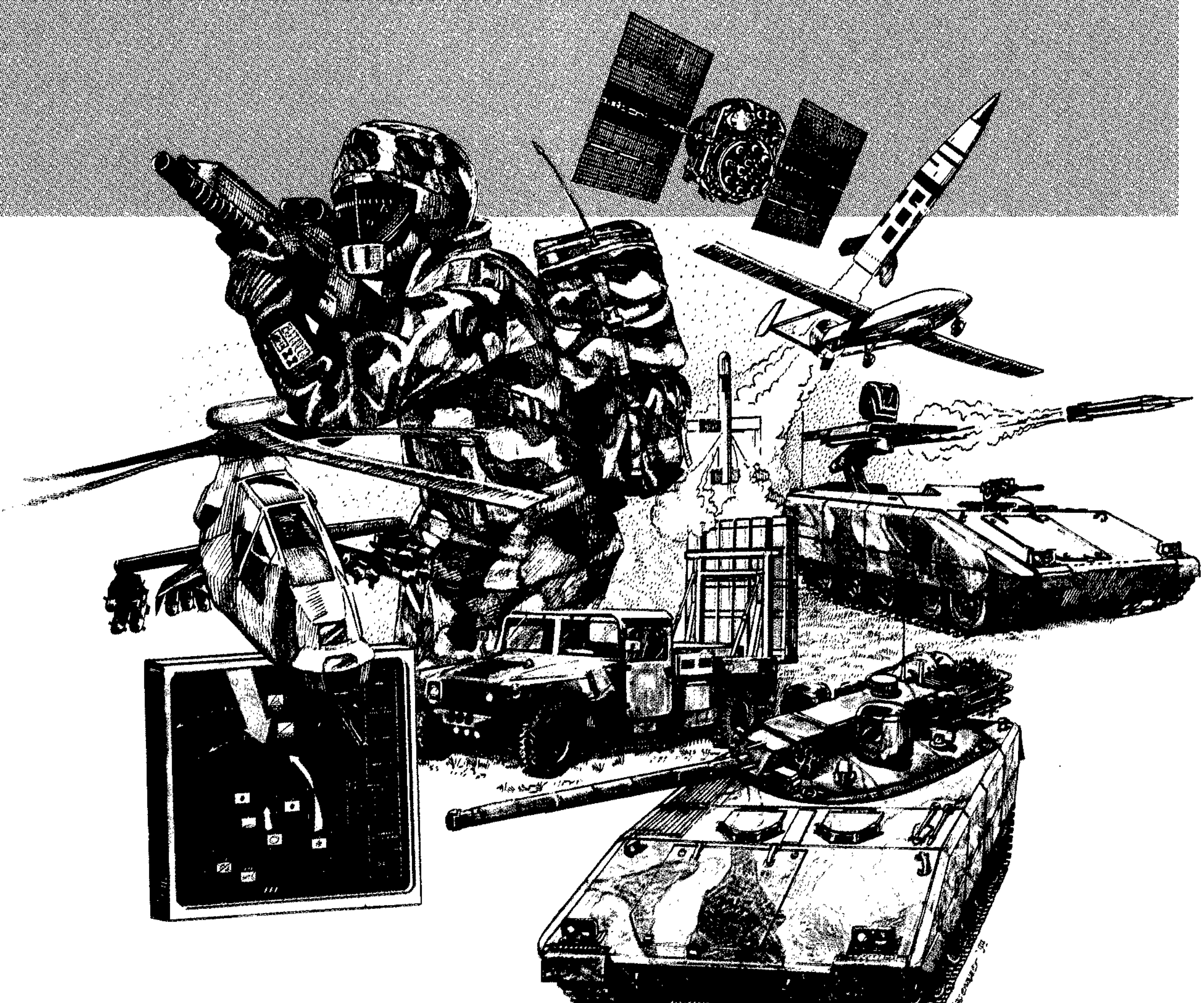
FISCAL YEAR 1997

ARMY SCIENCE AND TECHNOLOGY MASTER PLAN

VOLUME I



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Fiscal Year 1997

ARMY SCIENCE AND TECHNOLOGY MASTER PLAN

VOLUME I

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Deputy Asst. Sec. for Research & Technology
(SARD-ZT)
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DECEMBER 1996

DEPARTMENT OF THE ARMY
WASHINGTON, D.C. 20310

The Army Science and Technology Master Plan describes the technology investments we plan to enable America's Army for the 21st century, particularly our emerging long-term vision, the Army After Next. It is imperative in today's uncertain world that the Army maintains full spectrum dominance on the battlefield and prepares against future uncertainties throughout the entire spectrum of crisis.

Modernization of our Primary Mission Area Capability Enablers (P-MACE) is one of the keys to dominance on the battlefield and readiness for the challenges of the 21st century. The Army Science and Technology Master Plan details the technology we need to maintain an effective modernization program. Our modernization strategy will extend the life, improve the performance, and add new capabilities to the P-MACE systems while we develop completely new, technologically superior weapons for our 21st century Army.

Today, we are developing technology for tomorrow's Army -- a force capable of decisive victory against potential adversaries with unlimited access to an increasingly sophisticated global arms market. We are building a force to deter aggression and to conduct prompt and sustained operations on land to fulfill our mission requirements. To succeed, we must strengthen the capabilities of our world-class laboratories, strengthen our ties with industry, and keep a tight rein on development costs by reducing acquisition cycles.

We endorse the Army Science and Technology Master Plan. This plan provides the tools to maintain our decisive advantage and ensures that today's soldiers are well-equipped. Our brave men and women skillfully operate the most technologically advanced weaponry in the world. Tomorrow's soldiers deserve no less.

Dennis J. Reimer
General, United States Army
Chief of Staff

Togo D. West, Jr.
Secretary of the Army

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY
RESEARCH DEVELOPMENT AND ACQUISITION
103 ARMY PENTAGON
WASHINGTON DC 20310-0103

REPLY TO
ATTENTION OF

21 MAR 1997

This annual edition of the Army Science and Technology Master Plan serves as "top down" guidance from Headquarters, Department of the Army, to all Army Science and Technology organizations, and provides a vital link between the technology planning by the Department of Defense and the master plans of individual Army major commands, major subordinate commands, and laboratories.

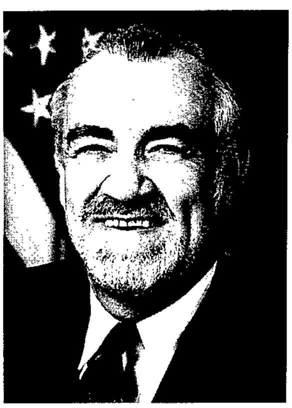
The Army Science and Technology Master Plan is a living, working document. It is our plan to enable America's Army to have full spectrum dominance on the 21st century battlefield. Our past investments in Army Science and Technology have paid huge dividends and led to advancements in both the military and commercial sectors. We now take for granted many of the so-called "breakthroughs." Currently, the Army Science and Technology community is focusing on Force XXI, particularly information dominance, as well as our far-term vision, the Army After Next.

We are committed to the timely demonstration of affordable weapon system concepts to meet the warfighters' needs in any current or projected threat environment. We have a world-class network of government and private Science and Technology capabilities to maintain land warfare technology superiority and to exploit rapid advances in information technology. And, we encourage reduced cost and early retirement of risk to support our acquisition reform initiatives. Most importantly, we are dedicated to America's soldiers and to ensuring that they have what they need when they need it. We are working hard today to maintain the most capable and modern Army in the world tomorrow and well into the next millennium.

We remain fully committed in sharing our strategies with the Science and Technology community at large. To that end, we are releasing this year's Army Science and Technology Master Plan on CD ROM.

A. Fenner Milton
A. Fenner Milton
Deputy Assistant Secretary
for Research and Technology

Gil Decker
Gilbert F. Decker
Assistant Secretary of the Army
(Research, Development and Acquisition)



Preface

The DoD Science and Technology program is divided into three areas, each designed to bring technology to various stages of maturity. The Basic Research (6.1) program exploits and identifies technological opportunities and provides an important interface with university and industry research. The Applied Research (6.2) program matures technology opportunities and evaluates technical feasibility for increased warfighting capability. The non system-specific Advanced Technology Development (6.3) program demonstrates technologies to speed the transition of matured technology into the system-specific Demonstration/Validation (6.4) program or directly into Engineering and Manufacturing Development (EMD) (6.5).

The *Army Science and Technology Master Plan* (ASTMP) is the Army's strategic plan for the science and technology program; it consists of two volumes.

Volume I has these seven chapters:

I. Strategy and Overview
II. Science and Technology Integration With Army XXI Requirements Determination
III. Technology Transition
IV. Technology Development
V. Basic Research
VI. Infrastructure
VII. Technology Transfer

Volume II contains annexes that, when combined with the Budget, Program Objective Memorandum (POM), and the Department of the Army Research, Development and Acquisition Plan, constitute the action plan for achieving the Volume I program.

Volume II contains the following annexes:

- Annex A—Science and Technology Objectives (STOs)
- Annex B—Advanced Technology Demonstrations (ATDs)
- Annex C—Interaction with Training and Doctrine Command (TRADOC)
- Annex D—Space, Strategic, and Theater Missile Defense Technologies
- Annex E—International Armaments Strategy and Near-Term Foreign Opportunities
- Annex F—U.S. Special Operations Command Technology Overview

The ASTMP is revised annually. Reader comments and suggested improvements are welcome. Please forward comments to:

Office of the Assistant Secretary of the Army (RDA)
ATTN: SARD-TS (Ms. Vannucci)
Room 3E479, Pentagon
Washington, DC 20310-0103

Data Fax No. (703) 695-3257

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CHAPTER I

STRATEGY AND OVERVIEW

Today's soldiers benefit from past commitments to a robust S&T program. Tomorrow's soldiers deserve no less.

"We are not the only nation with competence in defense science and technology. To sustain the lead which brought us victory during Desert Storm...recognizing that over time other nations will develop comparable capabilities, we must...invest in the next generation of defense technologies."

William J. Perry, Secretary of Defense

A. Introduction

The *Army Science and Technology Master Plan* provides Department of the Army Guidance to all Army science and technology organizations. The *Army Science and Technology Master Plan* also provides the link between Department of Defense technology planning and the plans of Army major commands, major subordinate commands, and laboratories. This strategic plan for the Army's science and technology program is based on the Army leadership's vision of the future Army and available resources. This plan is revised and approved annually by the Secretary of the Army and the Chief of Staff, Army.

Figure I-1. Army Vision

The Army Vision

"The world's best Army will be an Army that is Trained and Ready for Victory.
A Total Force of quality soldiers and civilians.

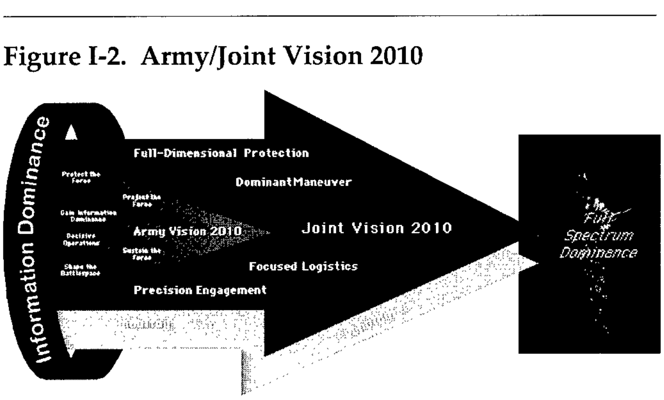
- A values-based organization
- An integral part of the Joint Team
- Equipped with the most modern weapons and equipment the country can provide
- Able to respond to our Nation's needs
- Changing to meet challenges of today... tomorrow...and the 21st Century."

Dennis J. Reimer
General, United States Army
Chief of Staff

B. Army Vision

The *Army Vision* is the conceptual template that provides a common direction to the Army to develop its unique land warfare capabilities within a joint framework of doctrine and programs (see Figure I-1). *Army Vision 2010* is the land component's response to meeting the operational concepts identified in *Joint Vision 2010*. *Army Vision 2010* identifies the operational imperatives and enabling technologies needed for the Army to fulfill its role in achieving full spectrum dominance (see Figure I-2). Army Vision 2010 also provides the connectivity between Force XXI, the Army's current modernization thrust, and the *Army After Next*, the Army's emerging long term vision. The *Army After Next* is a process to frame issues vital to the development of the U.S. Army beyond 2010 to around the year 2025. This process is charged with providing the Army's senior leadership with the long-term view of the Army's future,

Figure I-2. Army/Joint Vision 2010



including ensuring that the Army's long-term research and development programs connect to this vision (see Figure I-3).

C. Army Science and Technology Strategy

1. Vision

Supporting these current and future Army visions, the Army Science and Technology investment ensures:

- Timely demonstrations of affordable technology/weapon system concepts that enable
  - Decisive overmatch with minimum casualties
  - Force projection with full spectrum capability
  - Requirements definition/prioritization through experimentation
- S&T that reduces cost through
  - Early retirement of risk in materiel development programs
  - Support for acquisition reform
- World class network of Army-focused government and private S&T
  - maintain land warfare superiority
  - Leverage commercial information technology
  - Maintain smart buyer capability

Figure I-4 illustrates how the Science and Technology Investment Strategy supports Army Modernization Objectives into the next century.

2. Objectives

To support this vision, the Army has several strategic investment objectives (Figure I-5):

- Comply with and support the defense S&T strategy and the Army Vision, Army Vision 2010, and emerging concepts from the Army After Next.

Figure I-3. Army S&T Vision & Strategy

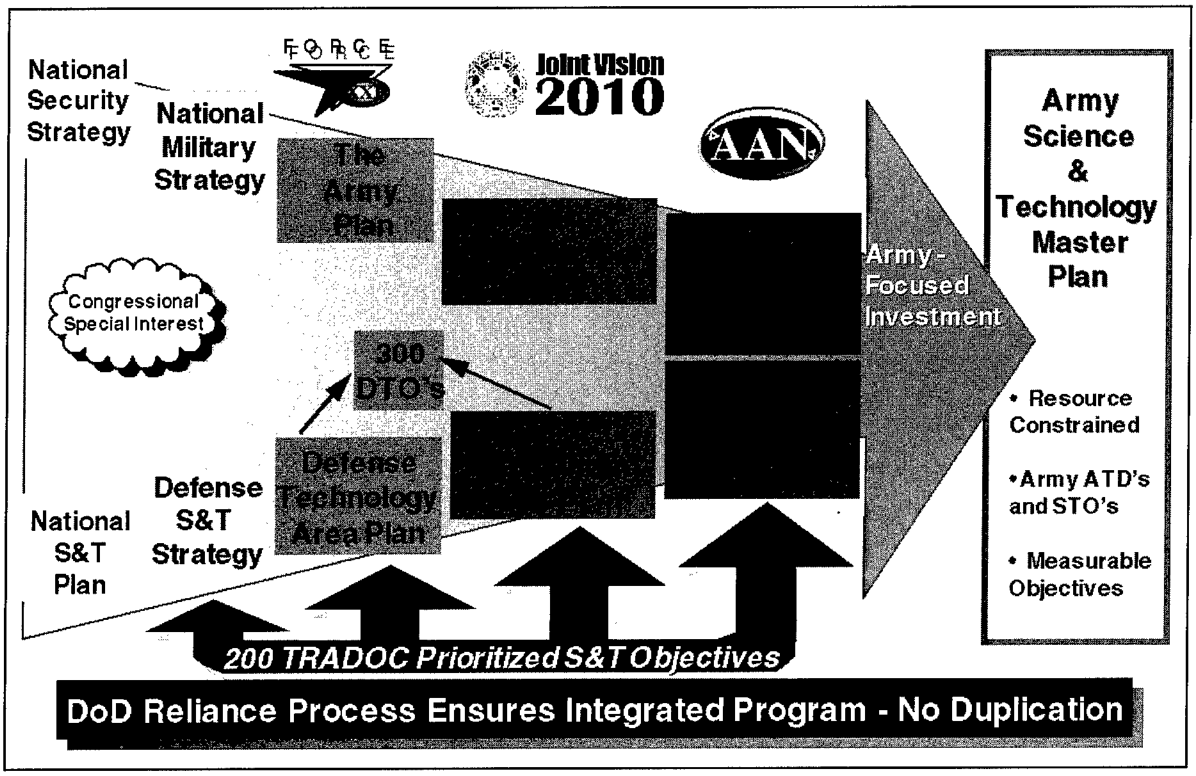


Figure I-4. S&T Strategic Investment Strategy

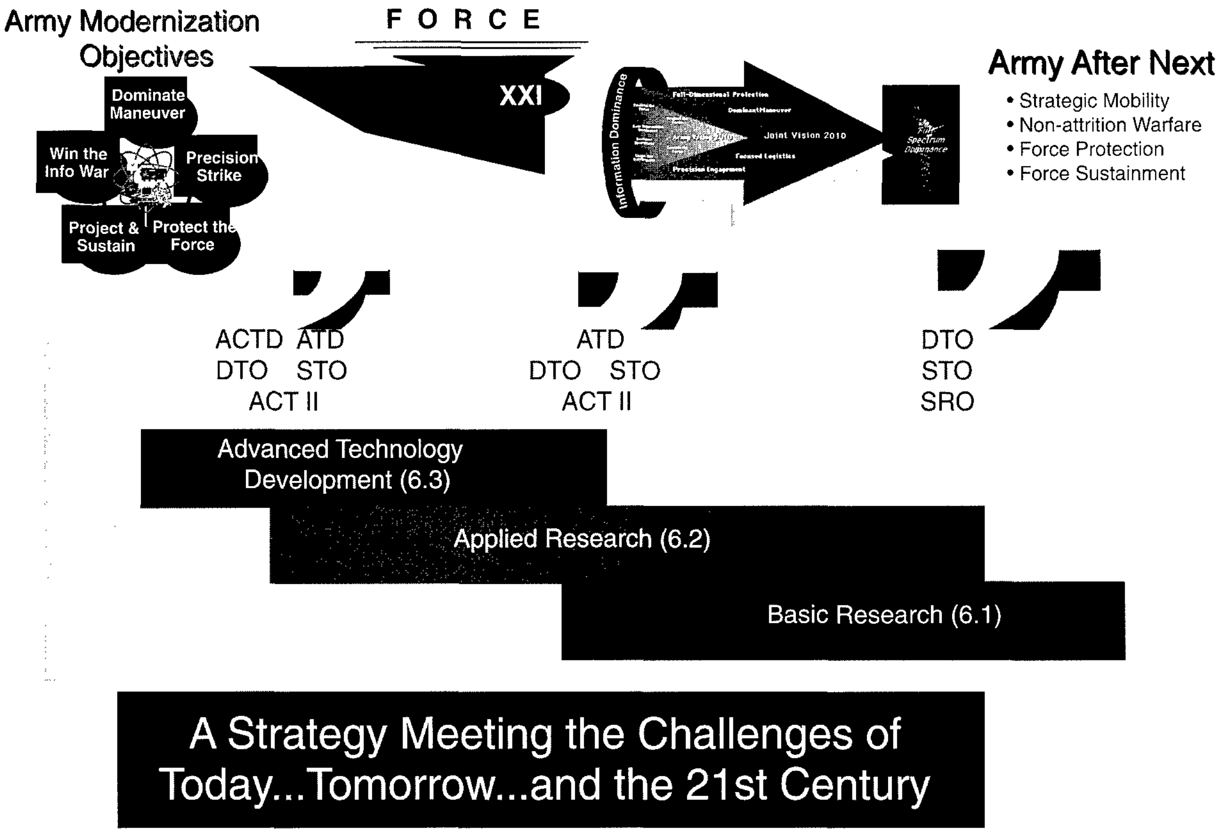
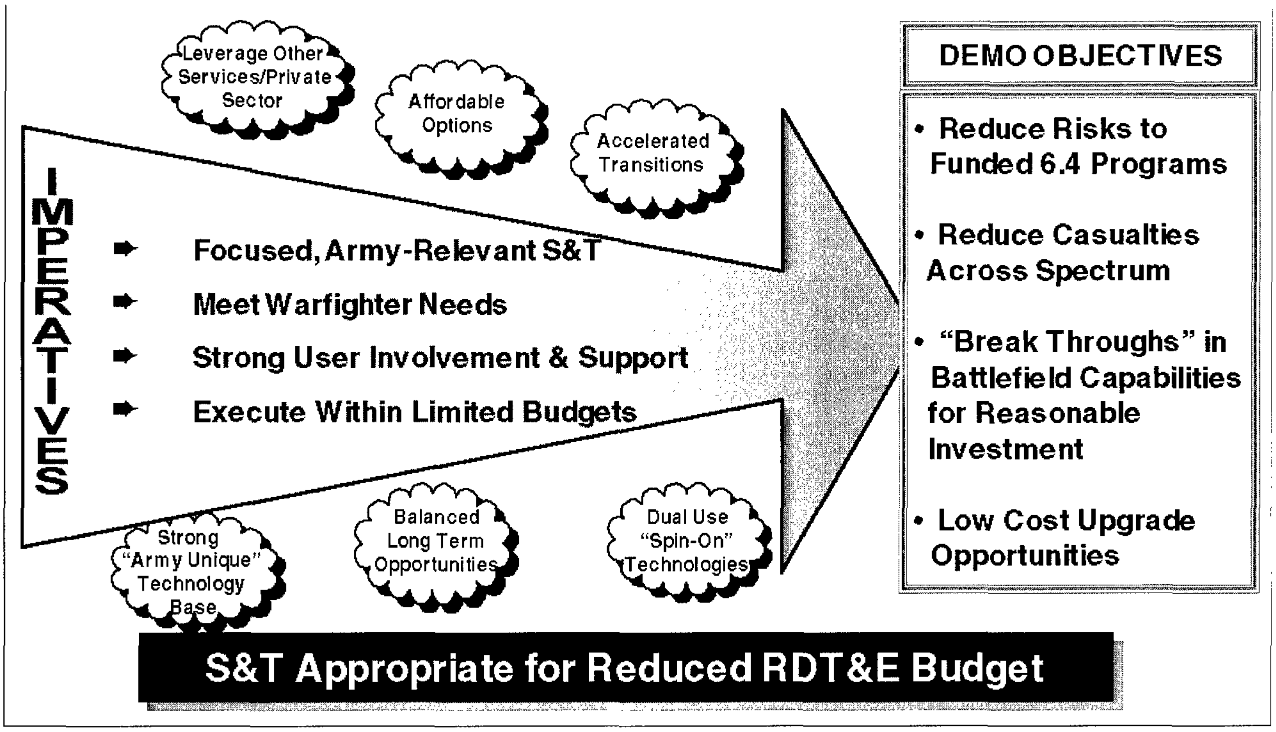


Figure I-5. Strategic Investment Objectives



- Conduct "world-class" relevant research.
- Strengthen the requirements process through:
  - System of systems demos
  - ATDs, ACTDs
  - S&T synchronized with TRADOC AWEs
- Support the Advanced Concepts and Technology II (ACT II) program.
- Provide affordable options with a focus on system upgrades.
- Improve technology transition—couple S&T to development programs.
- Improve technology transfer and "spin on" by forming partnerships with academia and industry.
- Stabilize S&T priorities and funding.
- Improve program execution and oversight.
- Attract, develop, and retain quality scientists and engineers.
- Downsize the infrastructure.

3. Planning Process and Oversight

The Army's science and technology strategy, as reflected in this year's Army Science and Technology Master Plan (ASTMP), identifies the science and technology investments needed to achieve this vision and supporting objectives. It provides an action plan for mobilizing government, industry, and academic resources. The ASTMP position in the overall DoD strategic planning hierarchy is shown in Figure I-6. Army leadership oversight of the Army S&T program is provided by the Army Science and Technology Advisory Group (ASTAG), which is co-chaired by the Army Acquisition Executive and the Vice Chief of Staff, Army (see Figure I-7). The Army Science and Technology Working Group (ASTWG) is co-chaired by the Army Science and Technology Executive (the Deputy Assistant Secretary for Research and Technology) and the Assistant Deputy Chief of Staff for Operations and Plans (Force Development).

Figure I-6. Hierarchy of Plans

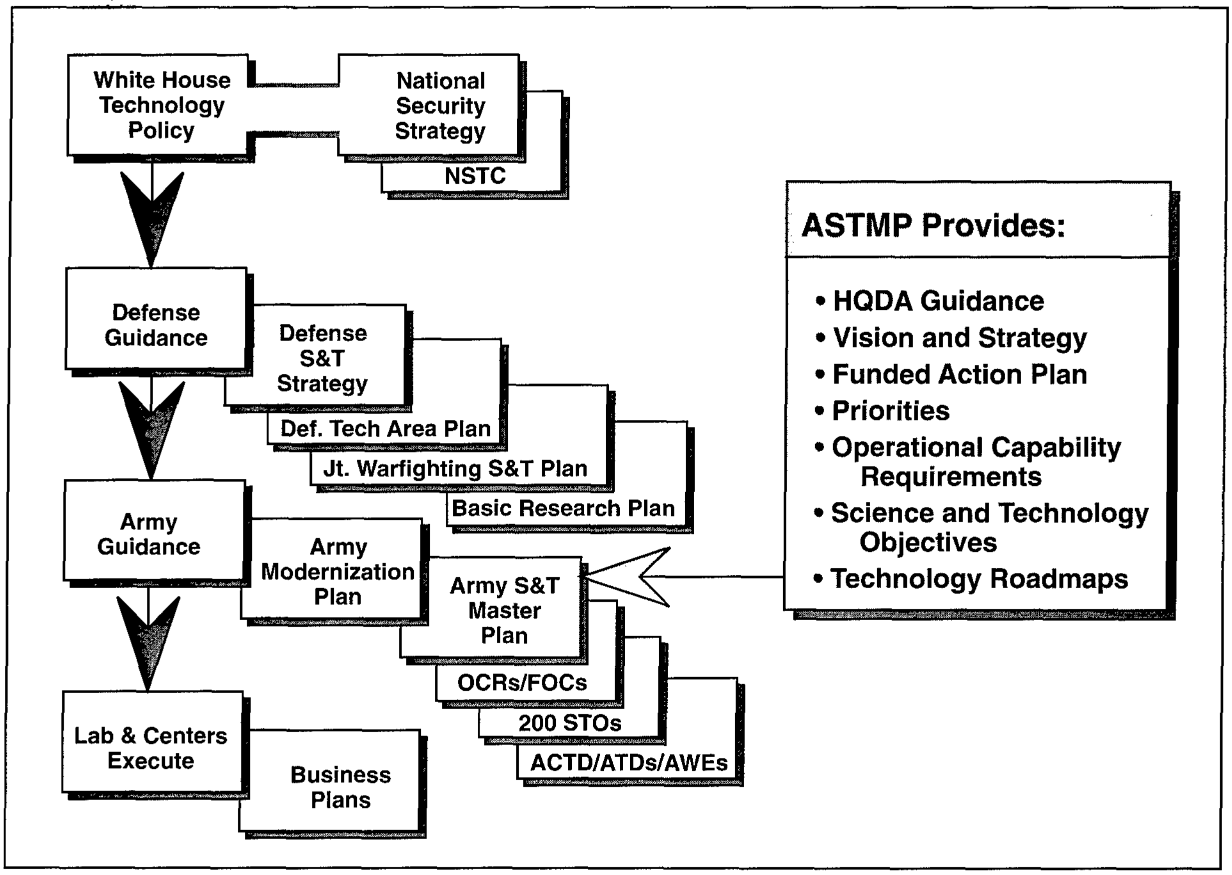
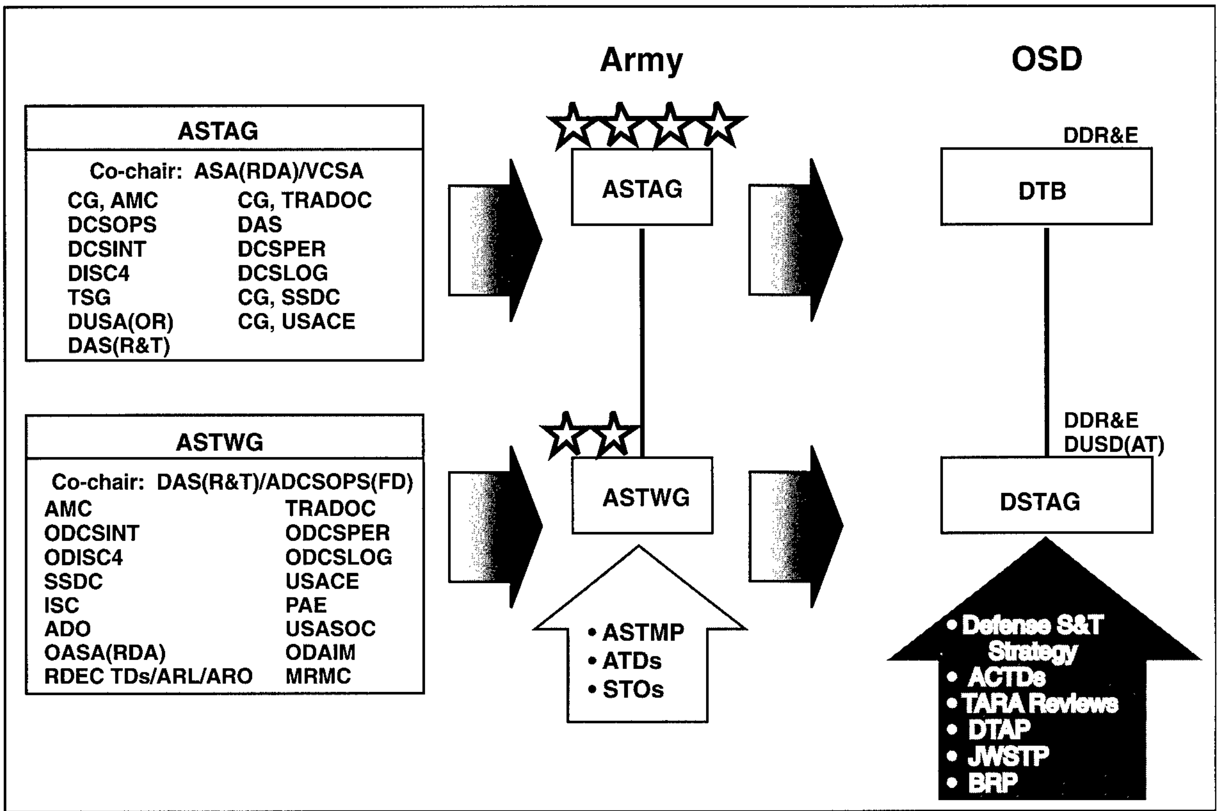


Figure I-7. Army/OSD S&T Oversight



The ASTWG provides general officer level resolution of pressing S&T issues prior to meetings of the ASTAG; recommends to the ASTAG revisions to the Army's S&T vision, strategy, principles, and priorities; and reviews and approves Advanced Technology Demonstrations (ATDs) and Science and Technology Objectives (STOs) (see paragraph 4, below). The overall planning process for the Army S&T program is shown in Figure I-8. The preparation and approval of the ASTMP is shown in the upper part of the diagram, and its progress through the overall Army planning and budgeting process is shown in the lower part.

4. Science and Technology Objectives (STOs)

To provide guidance to the S&T community, the Army has established a set of 200 Science and Technology Objectives (STOs). A Science and Technology Objective states a specific, measurable, major technology advancement to be achieved by a specific fiscal year (see Figure I-9). It must be consistent with the funding available in the current year budget and the POM for the FYDP years. Not every worthwhile, funded technology program will be cited as a STO in part because the Army must reserve some program flexibility for the laboratory or center director to seize opportunities within his or her organization, based upon the organization's local talents and resources.

The Army uses the STOs to focus and stabilize the program, practice management by objectives, and provide feedback to our scientists and engineers regarding their productivity and customer satisfaction. STOs are reviewed annually at a Joint AMC/TRADOC meeting and then reviewed and approved by the Army Science and Technology Working Group (see Figure I-10). STOs, revised as necessary to maintain currency and consistency with economic factors, ensure TRADOC input to the planning process and provide Army leadership guidance to S&T performing organizations. All Army Planning, Programming, Budgeting, and Execution System (PPBES) submissions, including budget estimates and execution plans should comply with the STO guidance. Descriptions of current STOs are given in Volume II, Appendix A, of this document and in the Army Science and Technology Management Information System (ASTMIS).

Figure I-8. Army S&T Planning Process

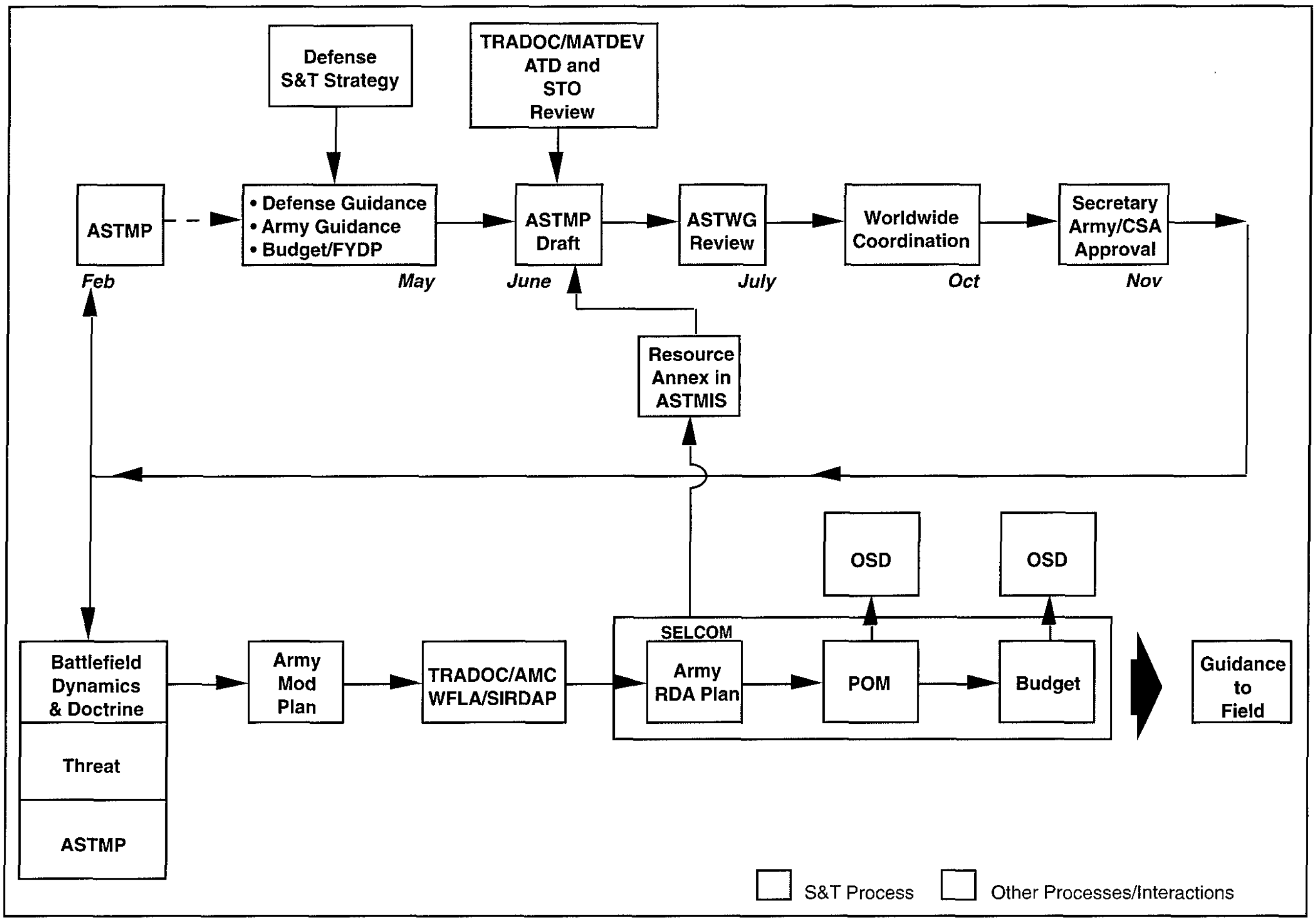


Figure I-9. Anatomy of a STO

ASTMP Reference

***III.D.12. Advanced Helicopter Pilotage Phase I/II*.** Develop and demonstrate advanced night vision pilotage technology and revolutionary helmet-mounted display (HMDS) technology for night/adverse weather helicopter pilotage. By FY95, develop Image Intensified sensor and fast (60 Hz) focal plane array for wide field of view (FOV) FLIR. By FY96, conduct flight demonstration and evaluation of sensor technology for wide FOV FLIR and Image Intensifier (I2). By FY98, demonstrate ultra-wide FOV (40° x 80°) night pilotage system -- HMDS and dual spectrum (IR and I2) sensors in a single turret -- to provide a significant reduction in pilot cognitive and physical work load.

Intermediate Milestones

Final Product w/ Metrics

Supports: Comanche, Enhanced Apache, Special Operations Aircraft, Rotorcraft Pilot's Associate ATD.

Applications

POCs

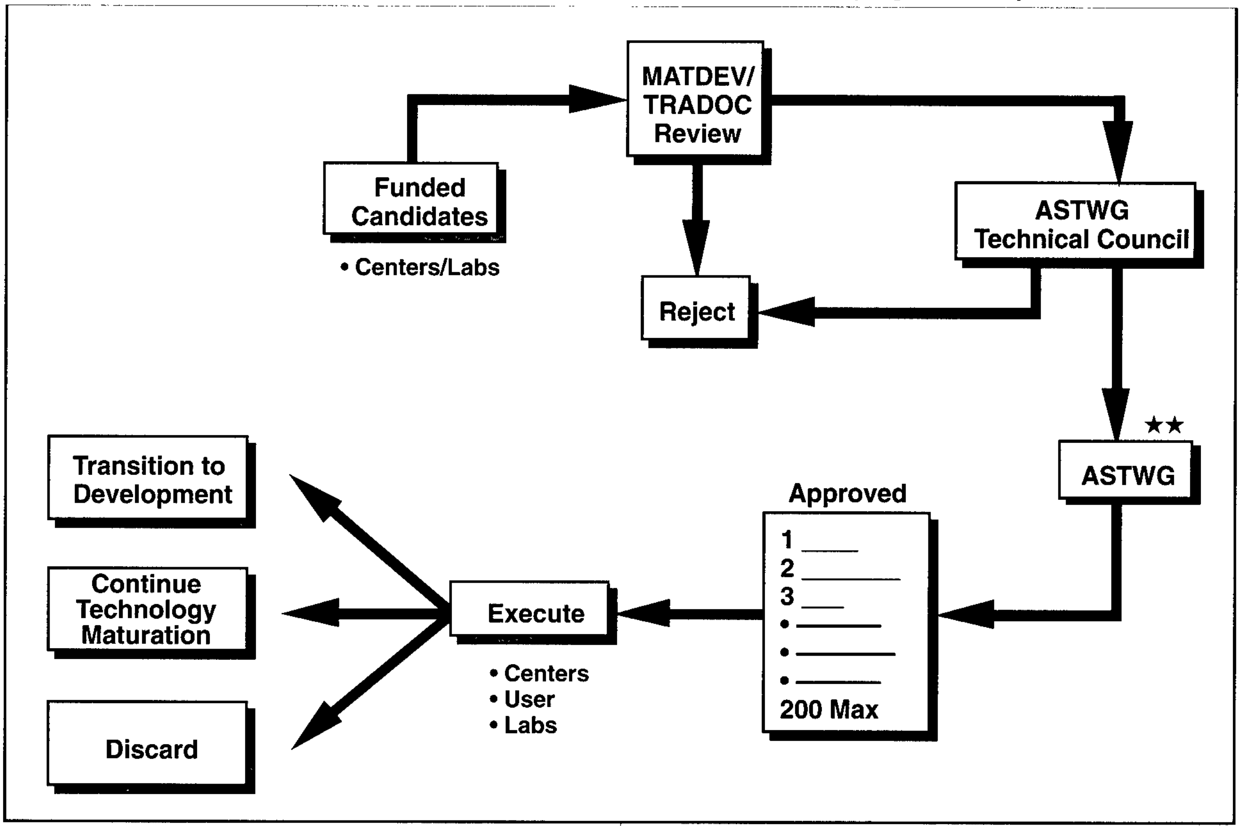
STO Manager:	TSO:	TRADOC POC:
Phil Perconti	Rob Saunders	Ted Huntley
CERDEC/NVESD	SARD-TT	Aviation Center & School
(703) 704-1369	(703) 697-8433	(205) 255-2571
DSN: 654-1369	227-8433	558-2571

POM Funding

Approved STO Guidance:

PE	Project	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03
63710	K86	4405	3255	2475	0	0	0	0	0

Figure I-10. Science & Technology Objective (STO) Process
A STO defines a specific measurable major technology advancement to be achieved by a given fiscal year.



5. Resourcing the Strategy

Figure I-11 shows how the 6.1, 6.2, and 6.3 funding categories relate to the overall acquisition process. Figure I-12 shows Army S&T recent and future funding levels.

- 6.1 Research includes all efforts of scientific study and experimentation with a high potential to significantly improve land warfighting capabilities. In the basic research category (6.1), the Army maintains a strong peer reviewed scientific base through which technological improvements to warfighting capability can be assessed and implemented. In addition to conducting in-house research, Army scientists monitor developments in academia and industry and evaluate the many proposals received for 6.1 funds. (See Figure I-13; also Chapter V, "Basic Research," and Chapter VII, Section C.1, "Programs with Academia.")
- 6.2 Applied Research includes all effort directed toward the solution of specific military problems, short of major development projects. The applied research category (6.2) includes the development of components, models, and new concepts. It represents a challenging management problem since individual research programs often support a number of identified needs. The Army addresses this challenge by linking individual research programs to the systems they support or make possible. In turn, the systems are linked to the Army's needs, as reflected in the various mission area strategies. Since research programs may readily contribute to needs in several different mission areas, the Army performs horizontal integration, or "cross mission area analyses," the results of which offer insights that may warrant reordering the 6.2 funding priorities. Thus, while the initial priority order is dictated by the most critical needs in individual mission areas, the horizontal analysis serves to incorporate a common sense overview to the process.
- 6.3 Advanced Technology Development includes all efforts directed toward projects which have moved into the development of hardware for testing for operational feasibility. Advanced technology development (6.3)

Figure I-11. Science and Technology Related to the Acquisition Process

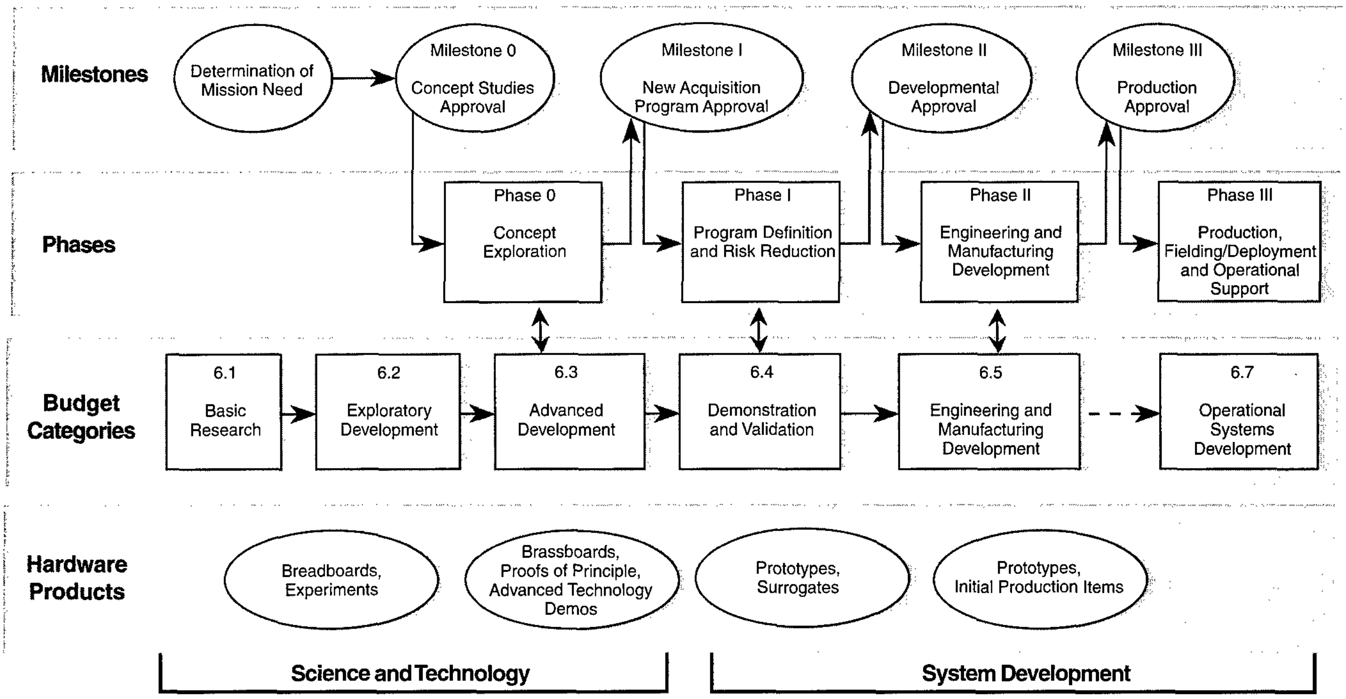


Figure I-12. Science and Technology Program Funding by Budget Category

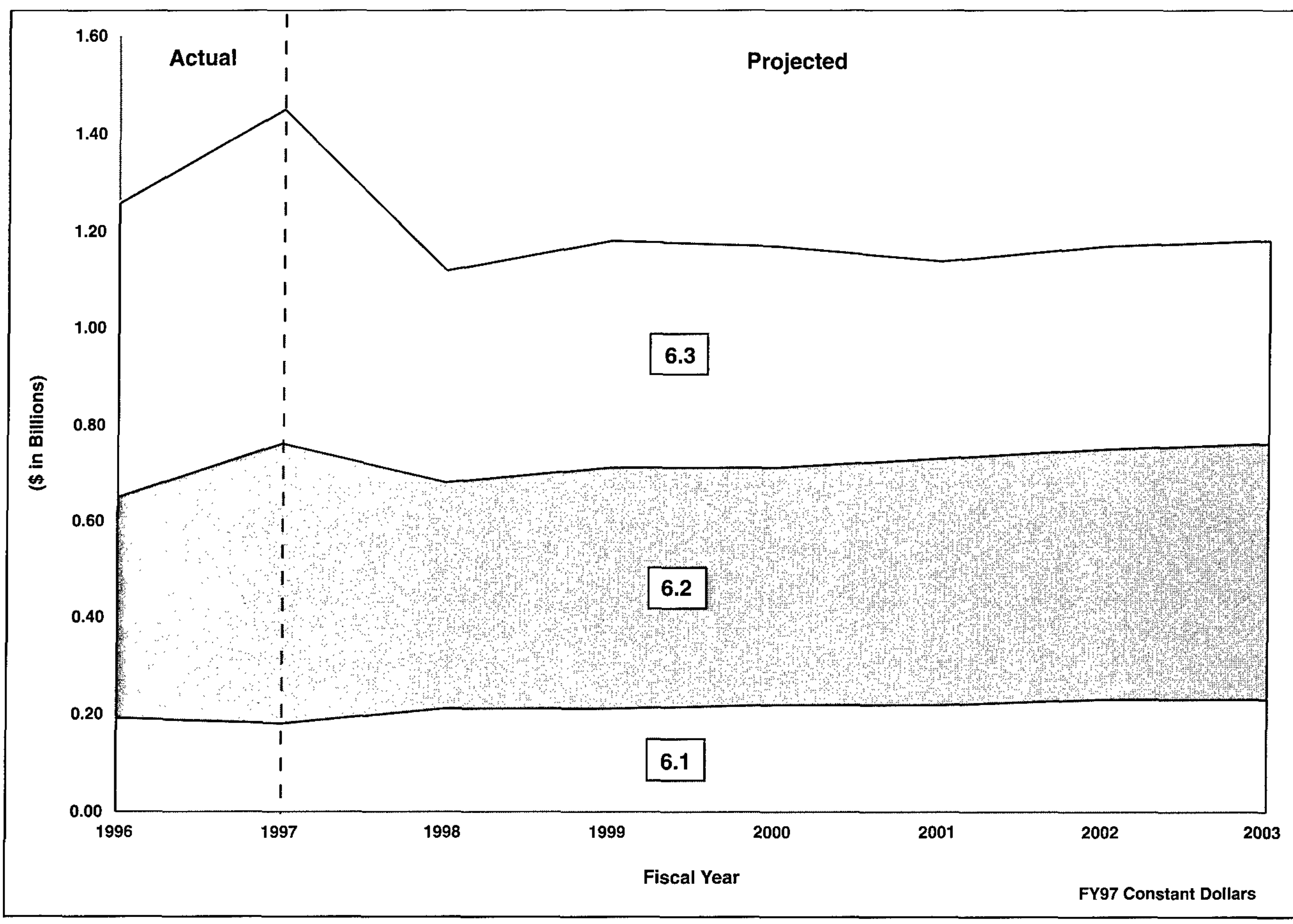
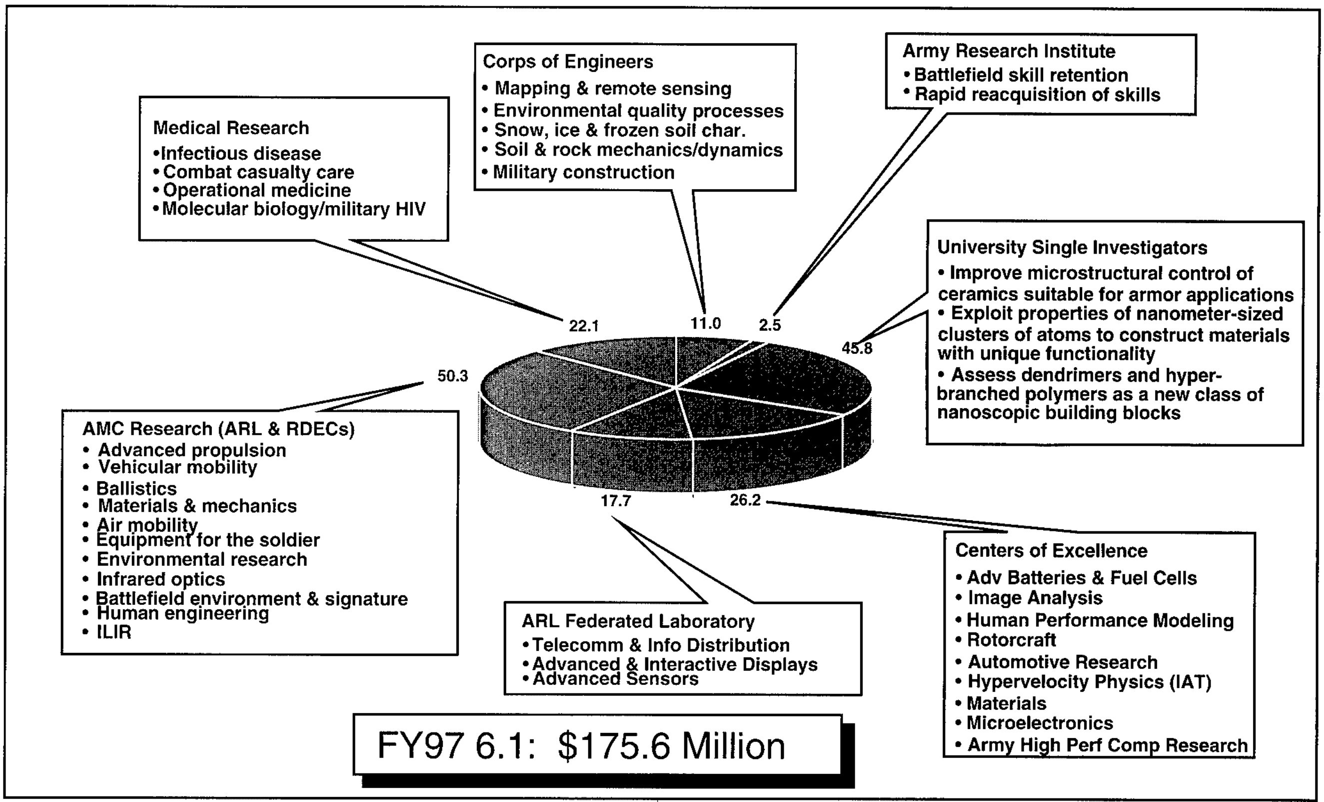


Figure I-13. Army Basic Research



provides the path for the rapid insertion of new technologies into Army systems, be they new systems or product improvements. In the 6.3 category, experimental systems are demonstrated to prove the feasibility and military utility of the approach selected. The Army establishes priorities based on which technologies will lead to the development of the most critically needed systems and product improvements. Figure I-14 shows the Army S&T FY97 6.3 budget breakout. The 6.3 category includes Advanced Technology Demonstrations (ATDs) and Advanced Concept Technology Demonstrations (ACTDs), many of which form the system of systems demonstrations.

The Army policy is to maintain stable funding for Army S&T. This stability principle of our investment strategy is consistent with the long-term nature of basic and applied research. Stability of focus and funding permits the Army's scientists and engineers to conduct meaningful long-range planning to ensure that the technologies required to address future warfighting needs will be available when needed. Figure I-15 shows the FY97 S&T budget breakout by program category and developing agency.

6. Technology Transfer

Technology Transfer covers all interactions with external organizations, whether transferring technology into or out of the S&T program. It should be distinguished from Technology Transition, which deals with the maturing of technology within the S&T program and transitioning it to development (6.4 or 6.5 programs). The Army continuously monitors new commercial developments looking for military applications. This "spin-on" of technology is of growing importance to the Army S&T program—not only from the domestic R&D programs but also from development overseas. Conversely, where military R&D is in the lead (e.g., rotorcraft, night vision, propulsion) technology transfer to commercial uses is actively pursued. Technology transfer is also made easier by the growing DoD adoption of commercial products, practices, and processes, and by the DoD Reliance initiative.

- Co-operative R&D Agreements. It is Army policy to actively market technology that can benefit the public and private sectors, and to respond quickly to requests for technical

Figure I-14. FY97 6.3 Program Breakout (Total = $693 Million)
52% of 6.3 funds for FY97 are committed to ATDs in AMC. The other 48% is spread among developing agencies as shown.

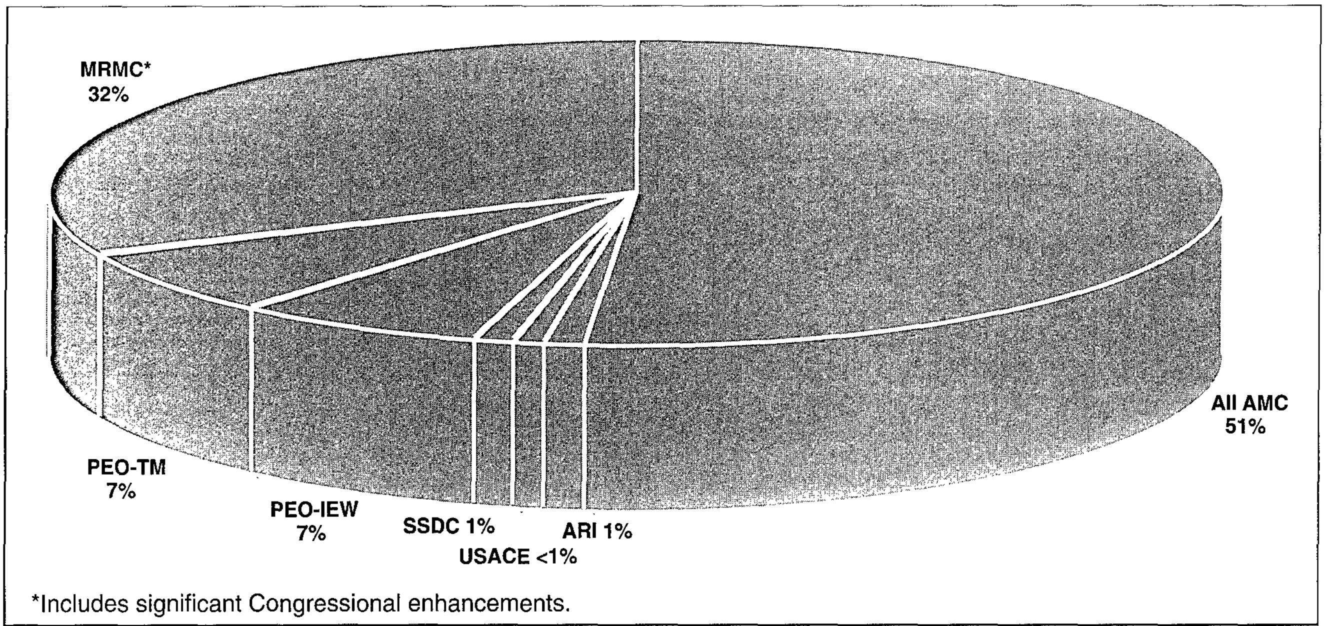
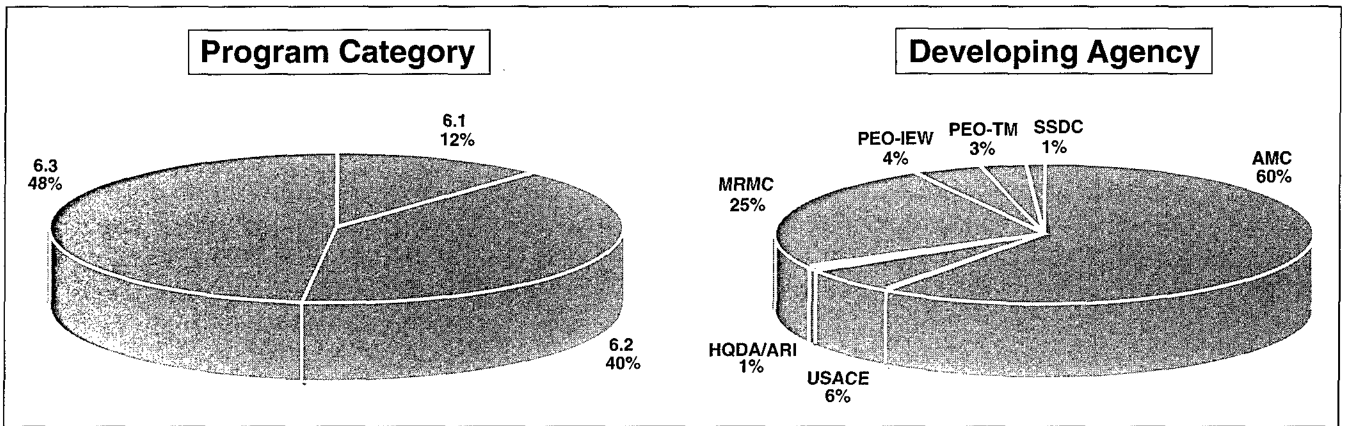


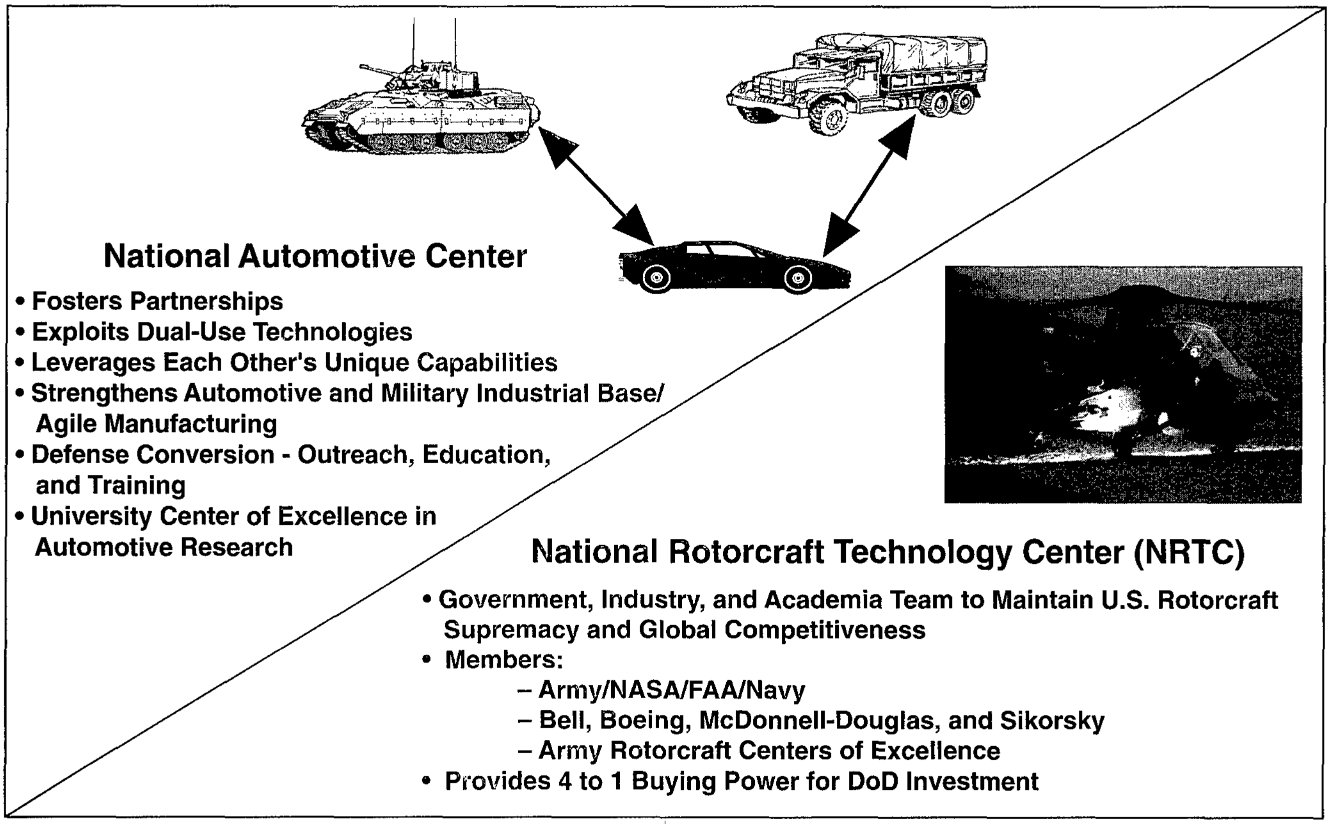
Figure I-15. FY97 S&T (6.1, 6.2, 6.3) Program Breakout



assistance. The mechanisms for accomplishing this are Cooperative R&D Agreements (CRDAs), the Construction Productivity Advancement Research (CPAR) program, Patent License Agreements (PLAs), and technical outreach programs. The cumulative Army totals from 1989 through FY96 are 895 CRDAs including CPAR agreements, and 73 PLAs. Of these agreements, 653 are still active (see Chapter VII.B.4 and B.5). The Army has more cooperative agreements than all the remainder of DoD combined.

- National Automotive Center (NAC). Recognizing the many dual use benefits to be exchanged among industry, academia, and government, the Army established the National Automotive Center in 1993 (see Figure I-16). The NAC is located at the U.S. Army Tank-Automotive Research, Development and Engineering Center, Warren, Michigan, and serves to facilitate the transfer of dual use automotive technologies from the commercial sector to the military and vice versa.
- National Rotorcraft Technology Center (NRTC). The NRTC, established in 1996, is a catalyst for facilitating collaborative rotorcraft research and development between the DoD (Army and Navy), the National Aeronautics and Space Administration (NASA), the Federal Aviation Administration (FAA),

Figure I-16. Dual-Use Technology



industry, and academia (see Figure I-16). It serves as the means to cooperatively develop and implement a rotorcraft technology plan and national strategy that can effectively address both civil and military rotorcraft needs.

- University Research Centers. Army policy is to foster basic research objectives by leveraging research programs in academic institutions. To accomplish this the Army sponsors research through the Army Center of Excellence Program and through the DoD University Research Initiative. Through these programs the Army focuses active research participation with more than 20 American universities (see Chapter V and Chapter VII.C.l).
- Small Business Innovation Research (SBIR). The Army has revised and strengthened the SBIR program to better leverage and support this innovative, entrepenural sector of our economy (see Figure I-17).

Many Army science and technology programs are conducted jointly or in coordination with the Air Force, the Navy, the Defense Advanced Research Projects Agency (DARPA), and other defense agencies assisted by Project Reliance. Other government agencies leveraged by the Army include the national laboratories of the Department of Energy (DoE), particularly for technologies such as directed energy and advanced materials; and the National Aeronautics and Space Administration (NASA).

Figure I-17. Small Business Innovation Research (SBIR) Process (<500 employees)

- Three Phase Program
  - Phase I (Technical Feasibility, 6 Months, $100K Max)
  - Phase II (R&D Effort, 2 Years, $750K Max)
  - Phase III (Commercialization, No SBIR Funds Used)
- DA Review/Selection Process
- $90–100M/Year
- Gaps Between Phase I and Phase II Efforts Reduced by SBIR Evaluation Board; Semi-Annual Transfer Offering Two Windows for Phase II Funding

Outside the United States, the Army seeks potential opportunities to increase the effectiveness of technology development through the sharing of RDT&E resources with NATO and major non-NATO allies. These joint and interagency programs are discussed in Chapter VII, Technology Transfer.

D. Army Modernization Strategy

A principal focus of U.S. military planning is on deterrence and regional crisis response. The Army, in concert with the other military services, is the strategic contingency force which must respond rapidly to regional crises and ensure that, if deterrence fails, we win decisively, swiftly, and with minimum casualties.

Army warfighting concepts to meet changing world realities are currently in a transitional period. JCS Pub 3-0, Doctrine for Joint Operations, establishes the fundamental principles, concepts, and doctrine for the Armed Forces of the United States in joint operations, as well as the doctrinal basis for U.S. military involvement in multinational and interagency operations. It defines the range of military operations, encompassed by war and operations other than war; describes the linkage between National and Combatant Command strategies; and provides a treatise on the operational art of war. JCS Pub 3-0 establishes the framework within which the doctrine, training, leader development, operations, and materiel of the U.S. Army must be generated and synchronized.

U.S. Army FM 100-5, Operations, was created within the construct of National Security Strategy and Policies, National Military Strategy, and JCS Pub 3-0. FM 100-5 undergirds all of the Army's doctrine, training, materiel, leader development, and soldier concerns. Doctrine is never static; although firmly rooted in the realities of current capabilities, it does look to the future in anticipation of intellectual and technological developments. FM 100-5 has led to establishment of six Battle Labs. The Advanced Concepts and Technology (ACT) II 6.2 Program, highlighted in Figure I-18, competitively funds industry at the $12–20 million per year level to participate in Battle Lab and Advanced Warfighting Experiments at the TRADOC Battle Labs. A more comprehensive explanation is presented in Chapters II and VII.

1. The Army Modernization Plan

The Army's force modernization strategy must anticipate the threat and design a defense long before that threat appears. The Army Chief of Staff has established five strategic objectives to guide this modernization. To enable the Army to implement that strategy, the science and technology program must be closely linked to Army force modernization, focusing on upgrades and advanced systems and concepts that meet Army needs and delivering timely and affordable technologies that support those advanced systems and concepts.

The *Army Modernization Plan* (AMP) is prepared by the Deputy Chief of Staff for Operations and Plans. The AMP formally states the Army's funded plans for force development and modernization and clearly articulates goals for specific modernization efforts through its mission area modernization annexes. It is the key document that assists in focusing and disciplining research, development, and acquisition (RDA) efforts over the long term (up to 30 years). The AMP promotes better communication between the Army and industry and allows for the early identification of programs that are not feasible given existing and planned funding. Chapter III of this volume presents an overview of the modernization plan annexes, highlighting required enabling technologies and important technology demonstrations for the Army's future upgrades and new systems (see Figure I-19).

Figure I-18. ACT II Program

- New Initiative to Fund Simulation and Field Tests at Battle Labs
- New Concepts Evaluation By TRADOC Battle Labs
- Proposals From Industry/Academia Through BAA
- Contract Management Through Lead RDECs Supporting Battle Labs
- Funding (6.2)
  $12–20M per year FY95-99

Figure I-19. Science and Technology Support for the Army Modernization Objectives

Modernization Objectives	Army Modernization Plan Annex (Chapter III Section Title)	ASTMP Section Reference
Project and Sustain the Force	Combat Maneuver (Soldier Systems) Combat Health Support Logistics Training	III.I III.J III.O III.P
Protect the Force	Air Defense Artillery Nuclear, Biological, Chemical	III.L III.K
Win the Information War	Intelligence and Electronic Warfare Command, Control, Communications, and Computers Space	III.F III.E III.Q
Conduct Precision Strikes	Aviation Fire Support	III.D III.N
Dominate the Maneuver Battle	Combat Maneuver (Mounted Forces) Combat Maneuver (Close Combat Light) Combat Maneuver (Engineer and Mine Warfare)	III.G III.H III.M

Modernization Plan Annexes set priorities among Army programs and integrate those programs into the total Army force (active and reserve components), thus allowing resources to be used more efficiently as modernization plans are completed and executed. Each annex is constrained to available and programmed resources and must be responsive to external factors such as changing threats, technology opportunity breakthroughs or delays, funding levels, and personnel assets.

2. Acquisition Reform

How we acquire and field these capabilities is critical to achieving the vision. The current acquisition process was designed for acquiring large, new weapon systems produced in quantity. It takes too long and costs too much for our post-Cold War budgets and today's technology turnover times. We must accomplish meaningful acquisition reform to be able to modernize the Army in a timely and affordable manner. We must become a world-class customer supported by world-class suppliers, using the full capabilities of America's total industrial base, governed by an acquisition system based on trust and partnership and incentivization of proper risk management, not risk aversion. As a minimum, we need to implement the following key improvements in our contracts:

- Require the Integrated Product and Process Development (IPPD) approach to acquisition.
- Identify and vigorously implement best business practices, products, processes, and standards while eliminating non-essential military standards.
- Exploit advanced distributed simulation for higher quality, lower cost, more timely concepts, more relevant requirements, and improved requirements-cost-schedule tradeoffs. Use these simulations to support development, testing, production planning, training, and mission rehearsal/planning.
- Obtain better, more timely customer requirements by integrated decision teams comprised of the warfighter, technologist, acquirer, and industry through TRADOC Battle Labs, Advanced Technology Demonstrations (ATDs), and Advanced Concept Technology Demonstrations (ACTDs).
- Procure on a price-based, best value approach vice lowest cost approach, thereby reducing cycle time, avoiding two separate (government and commercial) accounting systems, and reducing final cost to the taxpayer.
- Shift from a mass production assumption to lean, agile, and flexible manufacturing commensurate with smaller production orders and the need for continuous improvement.

Our acquisition development cycle times must allow us to field the winning-edge technology before our adversaries can develop or buy the same technology. A smaller Army must be better and more modern than any enemy. We cannot afford to do otherwise, lest we field mediocre equipment and lose our capability to win decisively with minimum casualties.

With our wide range of missions, global uncertainty, increased global technology transfer, and limited RDA budget, the Army must lead acquisition reform. For example, we require that all Acquisition Category I and II programs as well as all Advanced Technology Demonstrations (ATDs) have a Simulation Support Plan to ensure that advanced distributed simulations are used to improve acquisition by such time and cost-saving techniques as virtual prototyping from concept to production. The TRADOC Battle Labs are critical in simulating, experimenting, and assessing advanced technologies and concepts, thereby accelerating and improving both the requirement and acquisition processes.

We have required ATD to be sponsored by a Battle Lab and have at least one experiment performed at a Battle Lab. The Advanced Concepts and Technology (ACT) II program is funding competitively selected proposals from industry to demonstrate promising technology and prototypes of keen interest to all the Battle Labs. The Battle Lab Directors select the topics to be requested. Each of these will be tested and/or simulated at a sponsoring Battle Lab. The OSD Advanced Concept Technology Demonstration (ACTD) initiative will allow us to rapidly prototype promising technologies and provide real capabilities for the war fighting customer to evaluate. (See below, Section E.1, for more on the ACTD program.)

Horizontal Technology Integration (HTI), the application of common enabling technologies across multiple systems to improve the war fighting capability of the force, allows us to lower research and development costs and development time and obtain lower unit production costs by procuring larger quantities of the same subsystem for different weapons systems. We also benefit from a common logistics base for the same subsystems on multiple platforms. Key technologies that we will insert under this concept include the 2nd Generation FLIR, Battlefield Combat Identification Systems, Digitization, and Survivability Suite of Enhanced Systems.

A final consideration in the process is how we deal with industry. We must ensure through performance specifications and streamlined, tailored, page-limited solicitations that we give them maximum flexibility by telling them what we want as an end item and not how to do it or how to get there. The New Training Helicopter and T-800 engine procurements are examples. Furthermore, we must leverage commercial technologies, products, and processes and establish open architectures that facilitate future upgrades, leveraging the commercial information technology revolution and rapid advances in computers. These initiatives will shorten acquisition times for quality upgrades, reduce life-cycle cost, and allow us to easily integrate exciting new technologies as they become available.

E. Technology Transition

The number of major weapon systems new starts will decrease substantially the rest of this decade, while increased reliance will be placed upon technology insertion into existing systems via such upgrading mechanisms as engineering change proposals (ECPs), product improvement proposals (PIPs), pre-planned product improvements (P3I), and block improvement and multi-stage improvement programs (MSIP). These upgrade efforts may be intended to achieve one or a combination of the following objectives: improve performance, extend useful life, reduce operating and support costs, improve safety/survivability, or create a new major/revolutionary combat capability.

Technology demonstrations facilitate technology transition. They are performed to demonstrate that a technology is sufficiently mature and its contribution to military capability sufficiently understood to be ready for transition to the next acquisition stage, development. Because these are S&T efforts, no formal user-operator approved operational requirement document is needed. In fact, a technology demonstration should assist the user/operator to better understand the technology and to formulate a better statement of the requirement prior to entering development. Tech demos are usually funded with 6.3 funds, but may include 6.2. A major goal of the Army S&T program is now, where possible, to provide sufficient maturation to enter directly into Engineering and Manufacturing Development (EMD). A "Fast Track" initiative is underway for selected programs to facilitate this process. There are two types of technology demonstrations that greatly improve technology transition/insertion—ACTDs and ATDs.

1. Advanced Concept Technology Demonstration (ACTD)

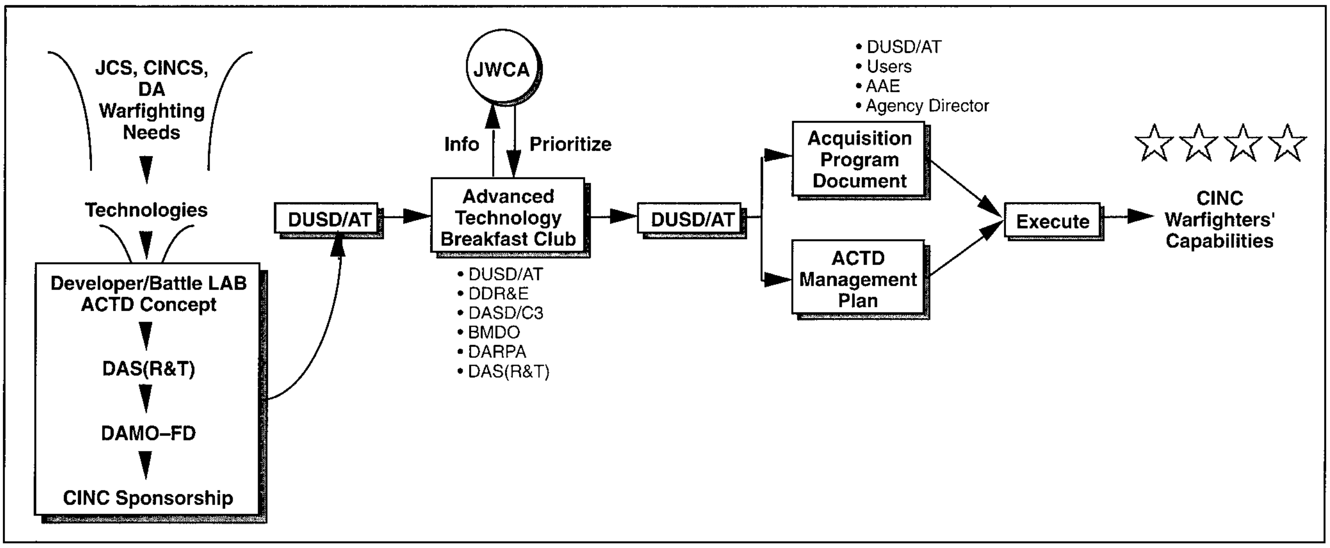
Advanced Concept Technology Demonstrations (ACTDs) provide a mechanism for intense involvement of the warfighters while incorporation of technology into a warfighting system is still at an informal stage. This allows iterative change of both the system construct and the user's concept of operation without the constraints and costs which are incurred when the discipline of formal acquisition is involved. ACTDs are user-oriented, even user dominated.

The ACTD has three driving motivations: (1) to have the user gain an understanding of and to evaluate the military utility before committing to acquisition; (2) to develop corresponding concepts of operation and doctrine that make the best use of the new capability; and (3) to provide limited, initial residual operational capabilities to the forces. ACTDs are of scope and scale sufficient to establish military utility. Residual capability is an important element in that the user is left with a residual capability for continued use for up to two years. This provides the commander a significant improvement in capability and the ability to refine the tactics and gain insight into the potential impact on doctrine. The ACTD process is shown in Figure I-20. All Army ACTD proposals must now have the approval of the Commander of TRADOC.

Formal requirements of the operational forces will be generated during the ACTD. The outcome of an ACTD is determined by the conclusions of the participating users. If the user is not prepared to initiate acquisition, the effort will terminate consistent with the user's reasons. If, on the other hand, the user determines that the demonstrated concept should be brought into the forces, there are two possible avenues. First, if large numbers are required, the system should enter the acquisition process at whatever stage good judgment dictates. Second, if only small numbers are required, it is preferable to modify the demonstration system appropriately and then to replicate it as needed. This latter avenue might apply to C3, surveillance, and special operations equipment as well as to complex software systems where evolutionary development and upgrading is preferred.

In FY97, the Army is participating in seven ACTDs, five as lead service: Precision/Rapid Counter-Multiple Rocket Launcher (see

Figure I-20. Advanced Concept Technology Demonstration (ACTD) Process
Rapid transfer of technology into warfighting capability.



Chapter III-F and Figure I-21), Rapid Force Projection Initiative (see Chapter III.N and Figure I-22), Combat Identification (see Chapter III.F and Figure I-23), Rapid Terrain Visualization (see Chapter III.H and Figure I-24), and Joint Logistics (see Chapter III.O and Figure I-25). The Army and Navy/Marine Corps are co-lead for two ACTDs: Joint Countermine (see Chapter III.M and Figure I-26) and Military Operations in Urban Terrain (MOUT) (see Chapter III.I and Figure I-27). Each of these ACTDs is composed of one or more Army ATDs (described in Chapter III and Appendix B, Volume II) as shown in the figure captions.

Figure I-21. Precision/Rapid Counter—Multiple Rocket Launcher ACTD (FY95-98)
Objective is to demonstrate an adverse weather, day/night, end-to-end, sensor-to-shooter precision, strike capability against high-value, time critical targets, including a specifically enhanced capability for USFK to defeat the North Korean 240mm MRL threat during H to H plus 48 hours.
Supporting ATDs:
- **Common Ground Station***
- **Guided MLRS**

(See Volume II, Annex B, for description of current ATD)
***Completed in FY95.**

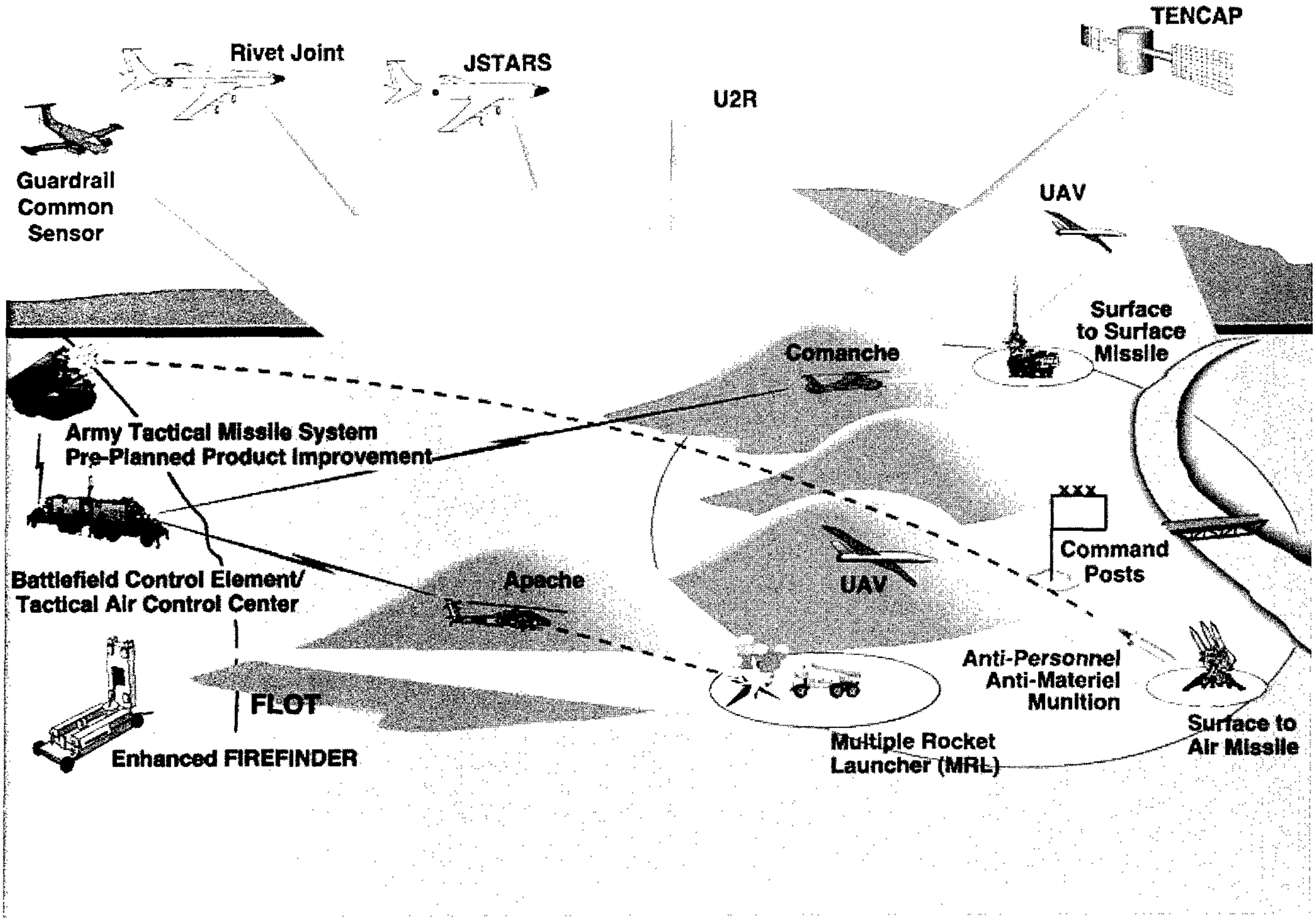


Figure I-22. Rapid Force Projection Initiative ACTD (FY94-01)
Objective is to demonstrate enhanced antiarmor and counterbattery capabilities for airlift constrained early entry forces including semi-automated target transfer from forward sensors to lightweight standoff weapons using C2 integration; and fully explore the capability to expand the brigade level battle space.
Supporting ATDs:
- EFOG-M
- Hunter Sensor Suite
- Intelligent Minefield
- Remote Sentry
- Guided MLRS
- Precision Guided Mortar Munition

(See Volume II, Annex B, for description of current ATD)

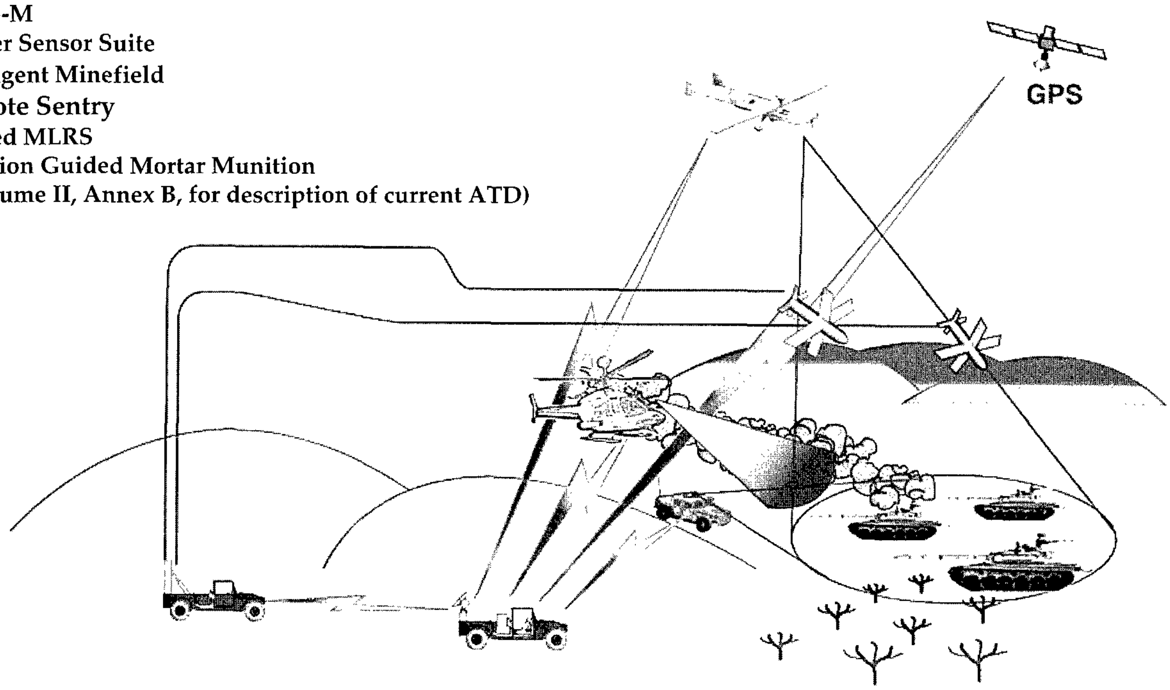


Figure I-23. Combat Identification ACTD (FY96-99)
Objective is to demonstrate a joint, integrated air-to-ground and ground-to-ground combat identification capability.
Supporting ATD:
- Battlefield Combat Identification

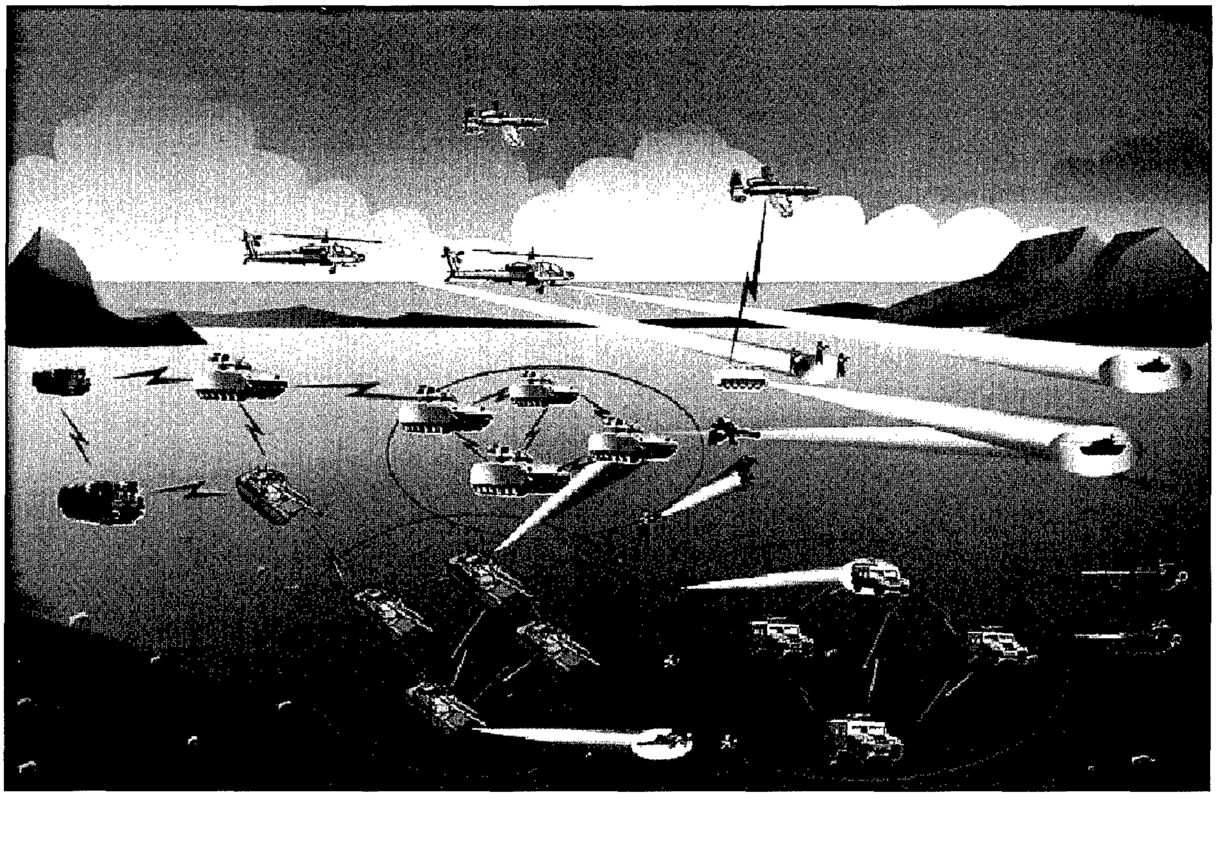
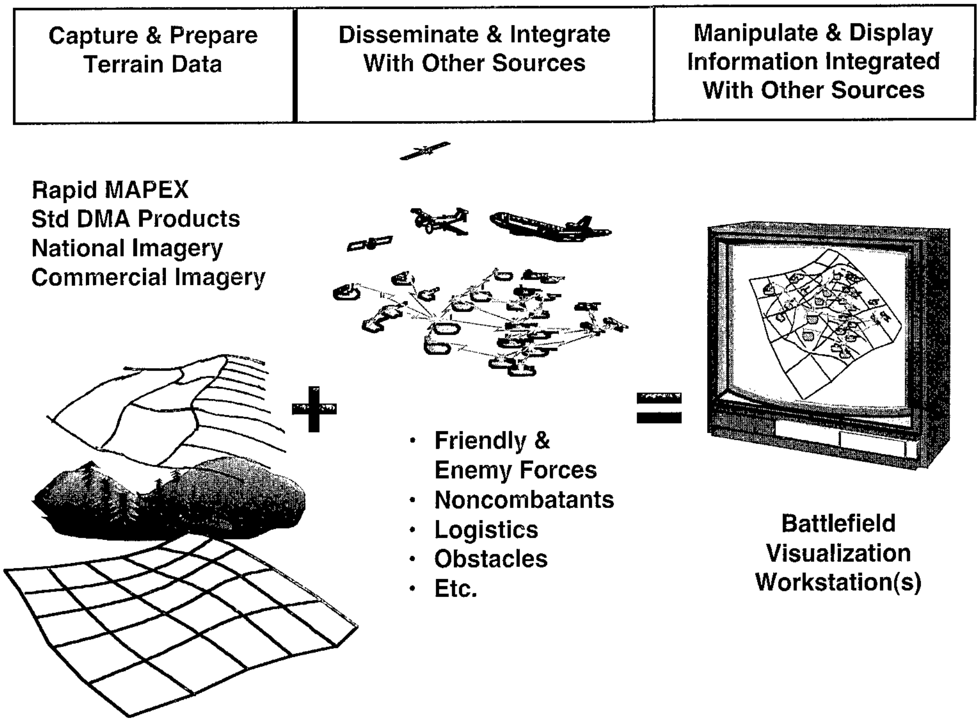
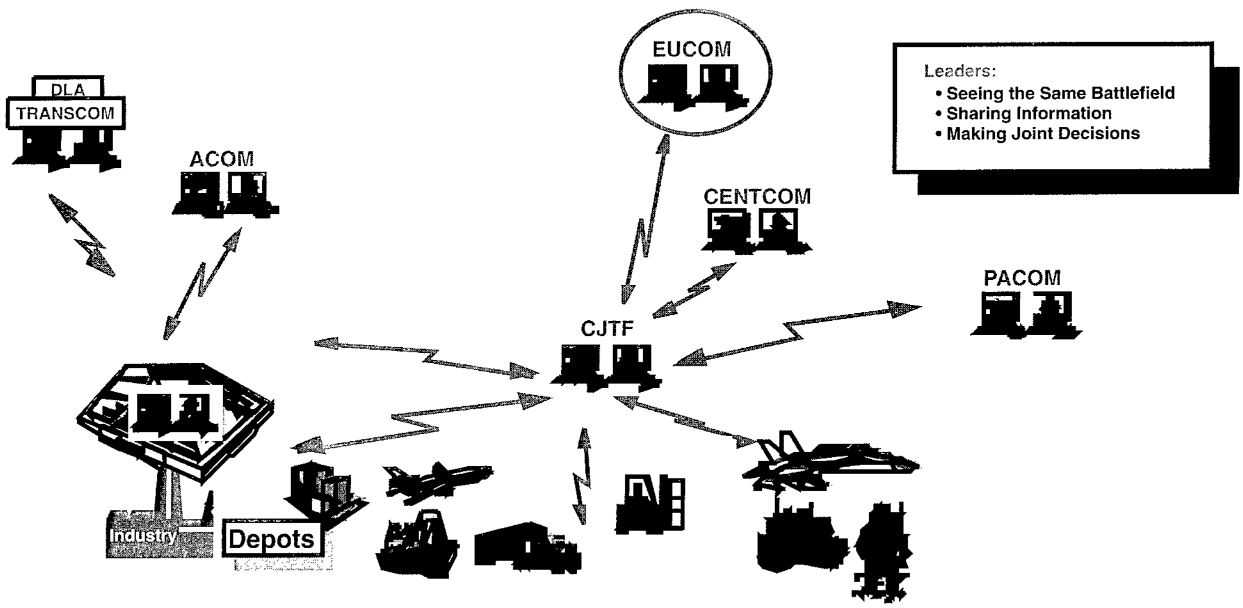


Figure I-24. Rapid Terrain Visualization ACTD



Supporting ATD: Battlespace C2

Figure I-25. Joint Logistics ACTD



Supporting ATD: Total Distribution.

Figure I-26. Joint Countermine ACTD (FY95-00)

Objective is to demonstrate a seamless amphibious and land warfare countermine operational capability from sea to land by coordinating Army, Navy, and Marine Corps technology demonstrators, prototypes, and fielded military equipment.

Supporting ATDs:

- Close-In-Man-Portable Mine Detector*
- Off-Road Smart Mine Clearance

*Completed in FY95

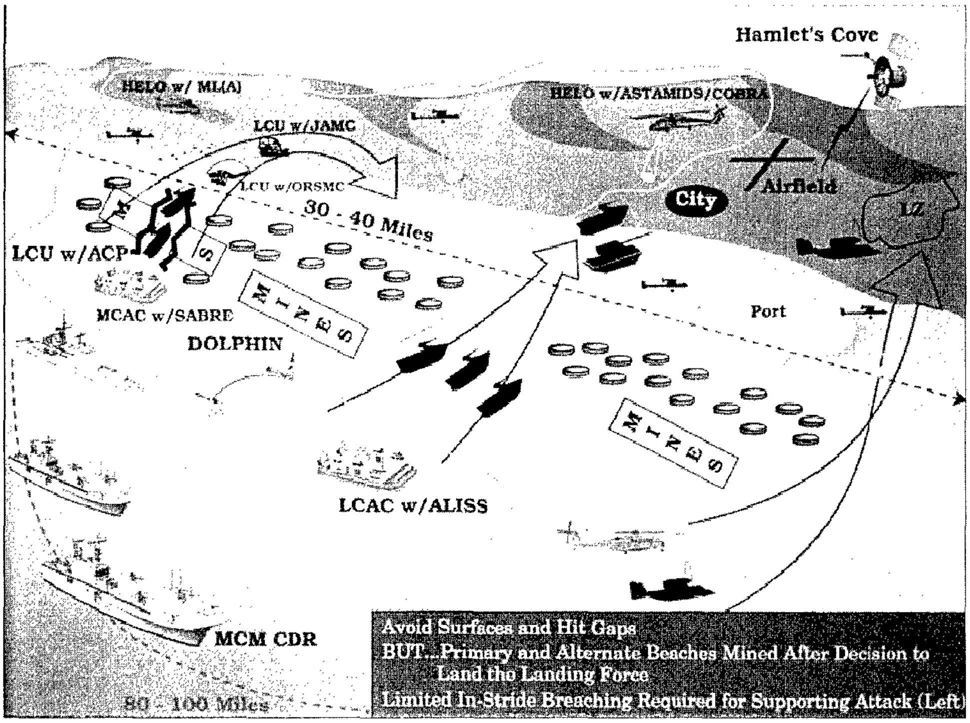
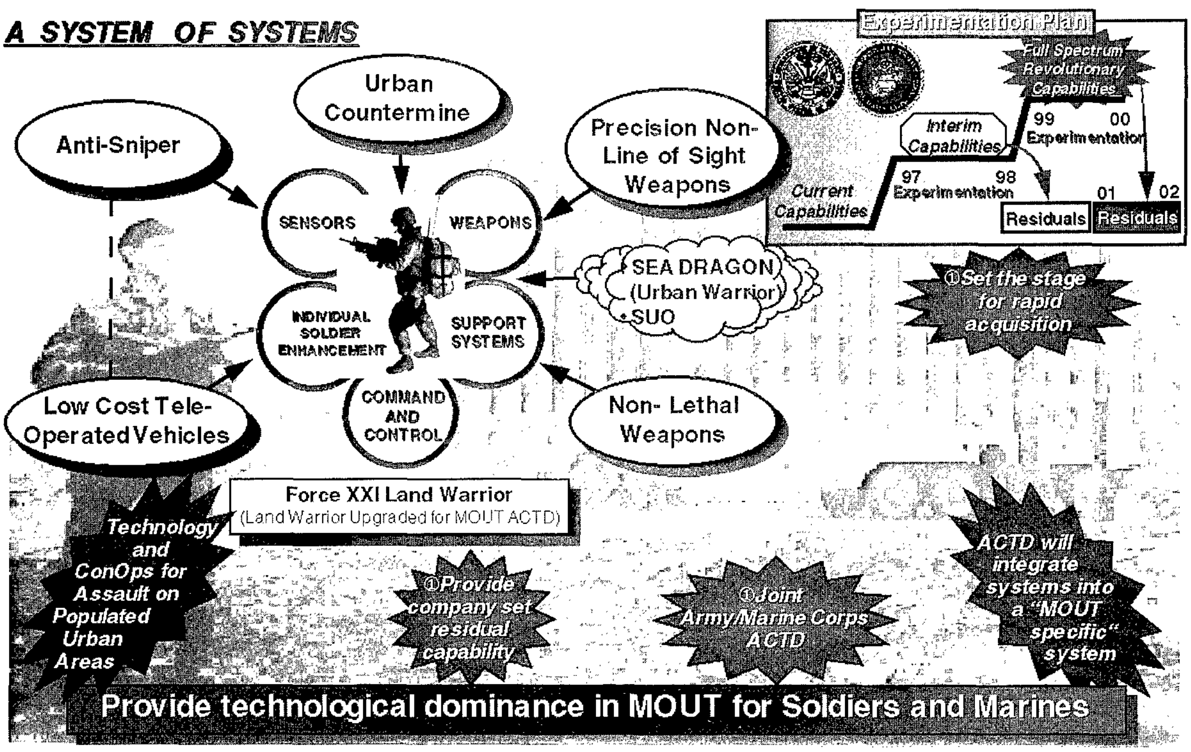


Figure I-27. Military Operations in Urban Terrain (MOUT) ACTD



2. Advanced Technology Demonstration (ATD)

ATDs are a category of technology demonstration characterized by the following: relatively large scale both in resources and complexity; operator/user involvement from planning to final documentation; testing in a real and/or synthetic operational environment; finite schedule, typically five years or less; cost, schedule, and objective performance baselines in an Army Technology Demonstration Plan approved by the DAS (R&T). Each ATD must meet or exceed exit criteria agreed upon by the warfighter and ATD Manager at program inception (well before the tests begin) before the technology in question will transition to development. The ATD approval process is shown in Figure I-28.

ATDs seek to demonstrate the potential for enhanced military operational capability and/or cost effectiveness. Active participation by the TRADOC School, as well as the developer, is required throughout the demonstration. At least one demonstration at a TRADOC Battle Lab is required, and an advanced demonstration simulation is strongly encouraged, as needed. This means approximately $250 million worth of ATDs will be evaluated at the Battle Labs this year. This helps each TRADOC School to develop more informed requirements and the materiel developer to reduce risk prior to the initiation of full-scale system development. Figure I-29 shows the crosswalk of the 23 ongoing ATDs with the Army Modernization Plan Annexes, STOs (see also Annex A of Volume II), and sections of Chapter III in this volume.

F. Defense Science and Technology Strategy

1. Vision

The DoD vision for Defense S&T is to develop and transition superior technology to enable affordable, decisive military capability.

Figure I-28. Army ATD Process

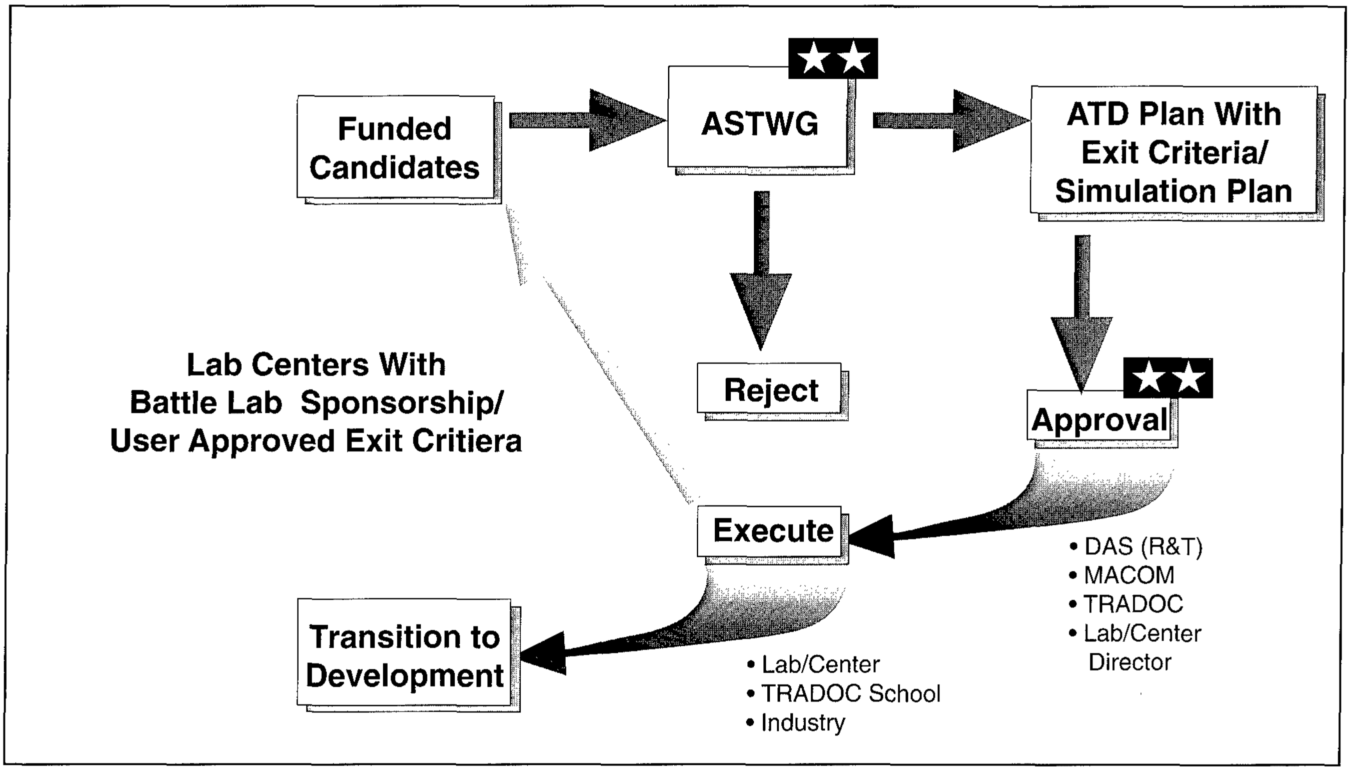


Figure I-29. Correlation Between Ongoing Army ATDs and the Army Modernization Plan

ATD	Army Mod Plan Annex Section		ASTMP Description Section	STO
	Primary	Secondary		
Rotorcraft Pilot's Associate	Aviation	IEW	III-D	III.D.01
Battlefield Combat ID	C4	IEW, Combat Maneuver, Aviation	III-E	III.E.07
Digital Battlefield Communications	C4		III-E	III.E.09
Hit Avoidance	Combat Maneuver		III-G	III.G.06
Composite Armored Vehicle	Combat Maneuver		III-G	III.G.01
Target Acquisition	Combat Maneuver		III-G	III.G.08
Enhanced FOGM	Combat Maneuver	IEW	III-H	III.H.03
Hunter Sensor Suite	Combat Maneuver	IEW	III-H	III.H.02
Precision Guided Mortar Munition	Combat Maneuver	Fire Support	III-H	III.H.04
Intelligent Minefield	Combat Maneuver		III-M	III. M.07
Total Distribution	Logistics		III-O	III.O.11
Objective Individual Combat Weapon	Combat Maneuver		III-I	III.I.01
Guided MLRS	Combat Maneuver		III-N	III.N.11
Vehicle Mounted Mine Detector	Combat Maneuver		III-M	III.M.08
Direct Fire Lethality	Combat Maneuver		III-G	III.G.10
Integrated Biodetection	NBC		III-K	III.K.03
Multispectral Countermeasures	Aviation		III-D	III.D.13
Air/Land Enhanced Reconnaissance and Targeting	Aviation		III-D	III.D.14
Battlespace Command and Control	C4		III-E	III.E.6
Future Scout and Cavalry System	Combat Maneuver		III-G	III.G.14
Multifunction Staring Sensor Suite	Combat Maneuver		III-H	III.H.15
Mine Hunter Killer	Combat Maneuver		III-M	III.M.9
Indirect Precision Fire	Fire Support		III-N	III.N.18

2. Joint Chiefs of Staff (JCS) Future Warfighting Capabilities Requirements

Military needs must determine what aspects of S&T the DoD pursues, and with what priority. It is the warfighter who enunciates those needs in this post-Cold War environment of widespread local warfare, potential for major regional conflicts, proliferation of weapons of mass destruction, and peacemaking operations. The JCS have identified 10 Future Joint Warfighting Capabilities most needed by the U.S. Combatant Commands. These needs, coupled with technological opportunity, guide S&T.

- Information Superiority, combining the capabilities of intelligence, surveillance and reconnaissance (ISR) along with command, control, communications, computers and intelligence (C4I)
- Precision Force, including the capability to destroy selected targets, both mobile and fixed, over wide areas and corresponding long ranges, with precision while limiting collateral damage.
- Combat Identification, with the capability to differentiate potential targets, mobile and fixed, over large areas with corresponding long distances, as friend, foe, or neutral.
- Joint Theater Missile Defense, using the assets of multiple Services and Agencies to detect, track, acquire and destroy enemy theater ballistic and cruise missiles.
- Military Operations in Urban Terrain with the capability to operate and conduct military operations in built-up areas and to achieve military objectives with minimum casualties and collateral damage.
- Joint Readiness and Logistics with the capability to enhance readiness and logistics for joint and combined operations.
- Joint Countermine, for assured, rapid surveillance, reconnaissance, detection, and neutralization of mines.
- Electronic Combat.
- Chemical/Biological Warfare Defense and Protection.
- Counter Weapons of Mass Destruction.

3. Guiding Principles for S&T Management

Five guiding management principles have been adopted by the military departments and defense agencies as the centerpiece of the S&T management strategy. These five guiding management principles are designed to place in the hands of our operational forces the best mix of capabilities possible, in the short and long term, by leveraging the best resources in DoD and the nation.

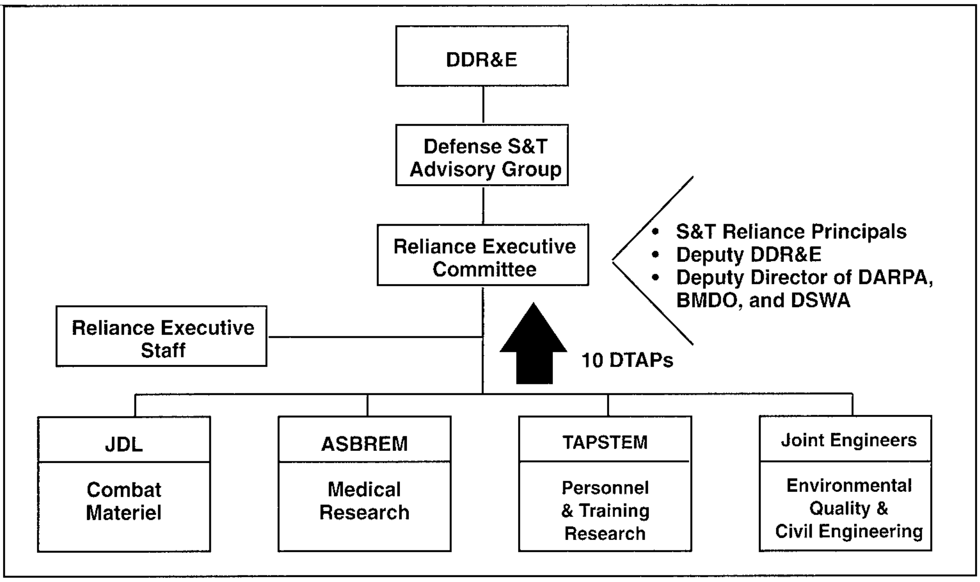
- Transition technology to address warfighting needs
- Reduce cost
- Strengthen the industrial base
- Promote basic research
- Assure quality

4. Management and Oversight

The S&T Program is planned, programmed, and conducted by the Military Departments and the Defense Agencies. The Departments are responsible for training and equipping the military forces and use the S&T program to provide warfighting and system options for their components. The Defense Agencies are responsible for specified generic and cross-service aspects of S&T. They also execute designated programs in support of national security objectives. The Defense Advanced Research Projects Agency (DARPA) is charged with seeking breakthrough technology and with investing in technologies that are dual use in nature, serving as a basis for both defense and commercial application.

The Director of Defense Research and Engineering (DDR&E) is responsible for the overall quality and content of the DoD S&T program. The DDR&E, aided by the Defense S&T Advisory Group (DSTAG) and the newly created Reliance Executive Committee, ensures that the program responds to the needs of the U.S. military and to the national goals embraced in the program's vision (see Figure I-30). The DDR&E assesses Service/Agency compliance with program guidance by means of Technology Area Review and Assessment (TARA) teams. Each TARA team, comprised primarily

Figure I-30. Defense S&T Management and Reliance

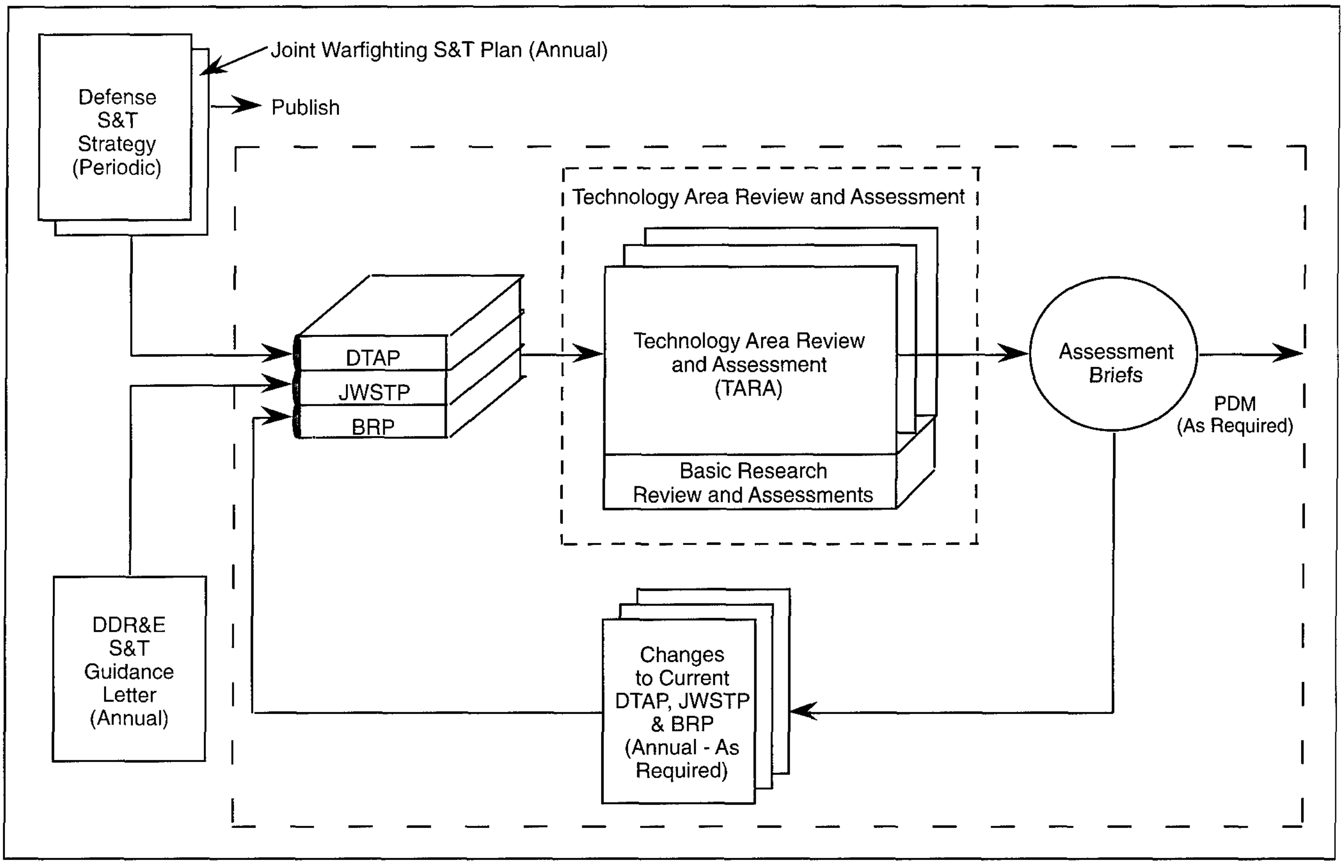


of outside technology experts and chaired by DDR&E technical staff, annually reviews the Defense Technology Area Plan (DTAP) prepared by joint expert teams of senior Service and Agency technologists. The process to annually update the DTAP, Joint Warfighting Science and Technology Plan (JWSTP), and Basic Research Plan (BRP) is managed by the Reliance Executive Staff; the TARA process is managed by the DDR&E. The 19 DTAPs (which remain the basis for the taxonomy of Chapter IV of the ASTMP) in FY95 were consolidated into 10 beginning in FY96, as shown in Figure I-31. The DTAP/JWSTP/TARA relationship and recent process instituted by the DDR&E with the DSTAG (see Figure I-32) are intended to make Defense S&T even more responsive to the warfighter and acquisition customers, increase the relevance and efficiency of the Defense S&T Reliance organization and

Figure I-31. TARA Teams and DTAPs

TARA Team and New DTAPS	Previous TAPS
Air Platforms	• *Part of* Aerospace Vehicles • *Part of* Aerospace Propulsion and Power
Chemical, Biological Defense and Nuclear	• Nuclear, Chemical, and Biiological Defense
Information Systems and Technology	• C3 • Computing/Software • Modeling/Simulation
Ground and Sea Vehicles	• Ground Vehicles and Watercraft
Materials/Processes	• Materials/Processes/Structures • Civil Engineering and Environmental Quality • Manufacturing Science and Technology
Medical and Biomedical	• Medical and Biomedical S&T
Sensors and Electronics	• Sensors • Electron Devices • Battlespace Environments
Space Platforms	• *Part of* Aerospace Vehicles • *Part of* Aerospace Propulsion and Power
Human Systems	• Human Systems Interface • Individual Survivability and Sustainability • Manpower, Personnel, and Training
Weapons	• Conventional Weapons • Electronic Warfare and Directed Energy Weapons

Figure I-32. Strategy, Planning, and Assessment Flow Diagram



process, and improve the overall effectiveness and efficiency of S&T strategic planning, programming, and assessment. The Deputy Under Secretary of Defense (Advanced Technology) is responsible for creation and oversight of ACTDs.

G. Infrastructure

A major element of the Army strategy is a strong, viable, high-quality in-house research capability. Laboratories and centers are the key organizations responsible for technical leadership, scientific advancement, and support for the acquisition process, including a smart buyer function. The Army S&T organizational structure is illustrated in Figure I-33; the funding breakdown by organization type is shown in Figure I-34. As shown in Figure I-34, ARO is funded entirely with 6.1. Less than 10 percent is used in-house; the rest goes to fund this nation's best university researchers. ARL is mission funded with basic research (6.1), applied research (6.2), and management support (6.6), of which it spends more than 40 percent with industry and academia. It is a corporate laboratory, serving many research, development, and engineering centers (RDECs), PEOs, and Defense agency customers. S&T funding for AMC RDECs is only about one-fourth of total RDEC funding. Approximately 60 percent of the RDEC S&T funding goes to industry.

1. Facilities and Equipment—Essential Foundation For Success

The Army owns a multibillion dollar network of RDT&E facilities located at over 100 sites worldwide (see Chapter VI, "Infrastructure"). The technological demands in many fields, including medicine, microelectronics, photonics, materials, and manufacturing processes, dictate the need for modern, excellent facilities. Consequently, the Army is consolidating specialized facilities, eliminating aging and technologically obsolete facilities, and using the capabilities of contractors and

Figure I-33. Army S&T Organization

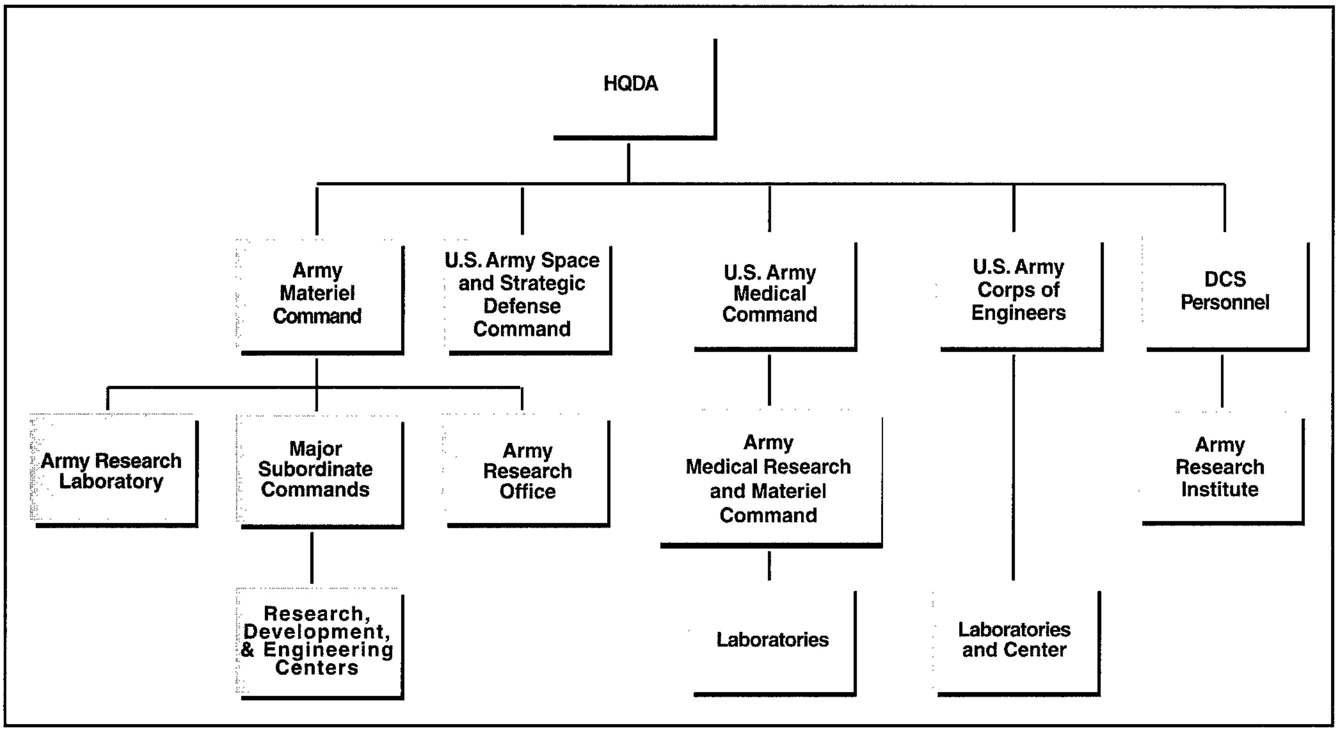
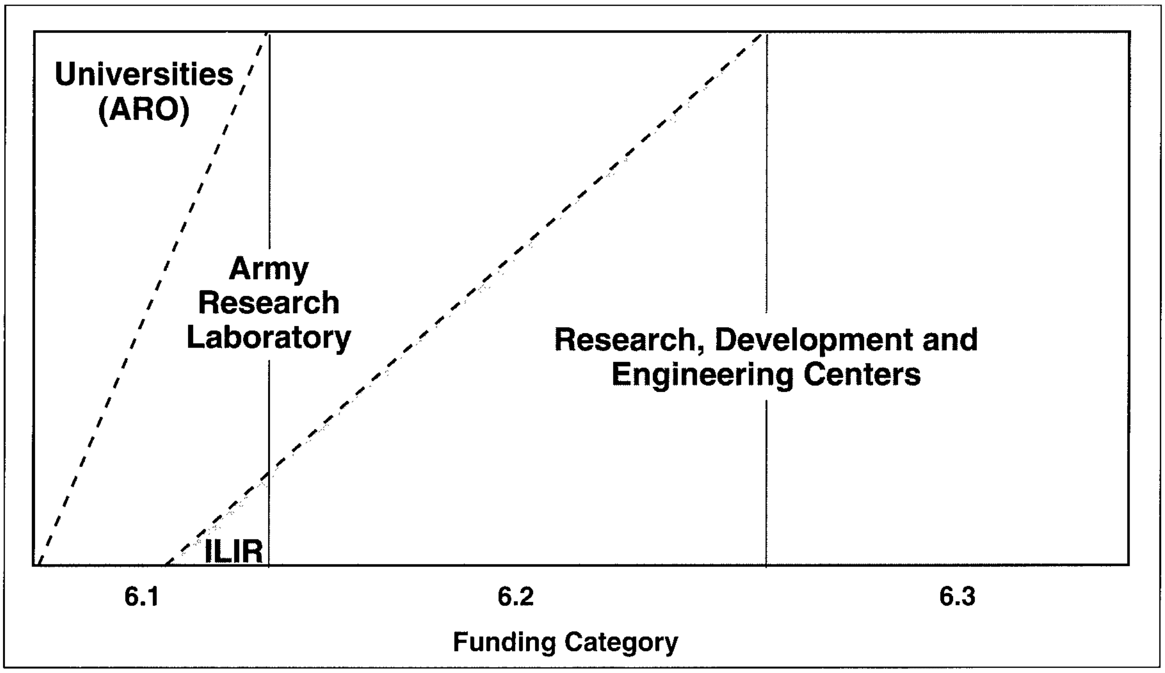


Figure I-34. S&T Funding Strategy



other military services. At the same time, Army RDT&E manpower is being drawn down (see Figure I-35). The new Walter Reed Army Institute for Research (WRAIR) is an example of long overdue modernization of in-house facilities which focuses on those unique capabilities that truly must be owned by the Army itself, consistent with Project Reliance and Base Realignment and Closure (BRAC) processes. The 1991 BRAC mandated organizational consolidation and geographic collocation of ARL at two main campuses, Adelphi and Aberdeen, MD. Construction has started on a new materials research facility at Aberdeen and new laboratory and office facilities at Adelphi to accommodate incoming personnel and maintain mission synergy.

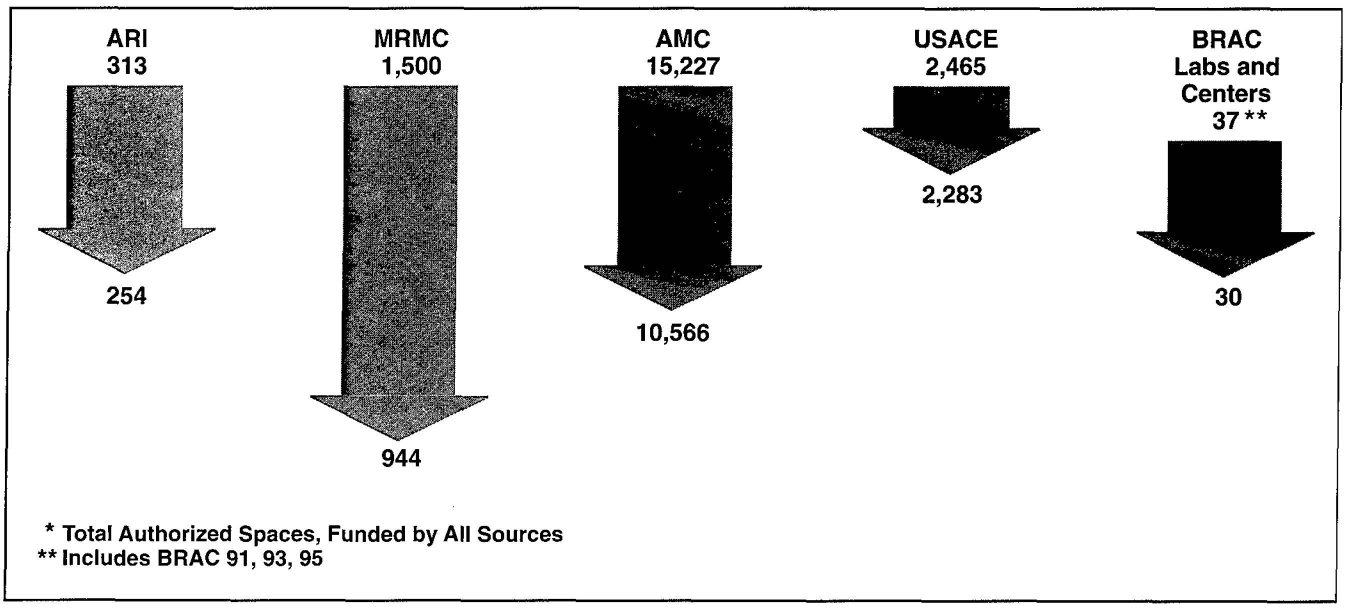
In the future, the Army will use more automated equipment, computer-based research support, and technological networking of researchers to yield more work per scientist and engineer. This strategy will be very important as the Army reduces the size and changes composition of its civilian work force. Advanced distributed simulation is compressing research and technology development cycle times. The use of physical simulation tools, computer modeling, and other highly automated systems is necessary to both product and manufacturing process technologies, and is pivotal to the future of the Army R&D establishment. These issues are discussed further in Chapter VI.

2. People—The Key To The Future

Approximately 10,000 in-house personnel in 30 laboratories, centers, and institutes are funded by S&T. Working at a diversified set of facilities, ranging from solid-state physics laboratories to outdoor experimental ranges, these personnel conduct research, technology development, "smart buyer", and product support activities for the total Army. Highly motivated, competent, well-trained people are essential to the success of the Army S&T strategy. Keeping the in-house work force technically competent in a rapidly changing environment is a major objective for the future. The DoD Laboratory Quality Initiative (LQI) allows revised procurement rules and investment in facilities which will assist in meeting the challenge. Laboratory consolidations to increase the critical mass of scientific personnel, laboratory modernization, the experimental use of wider pay bands, special pay, and other OSD and Army initiatives are being studied to remedy this problem.

Demographic projections for college graduates indicate a declining number of engineers and scientists in the period to 2015. The Army is the DoD leader in Youth Outreach (see Figure I-36), Historically Black College/University/Minority Institution (HBCU/MI) (see Figure I-37), and Small Business Innovation Research (SBIR) programs. Every university research

Figure I-35. RDEC and Lab Infrastructure (Personnel) Drawdown—FY89 to FY99*



center of excellence and federated laboratory is required to have an HBCU partner who performs a significant amount of the research. Army stay-in-school and summer intern programs have convinced many students to study science and engineering (see Figure I-38).

Figure I-36. Youth Science Activities

GOALS:
- Conduct, Promote, and Sponsor Science, Math, and Engineering Education
- Promote Competent and Diverse Technical Workforce
- Implement EO 12821 and 10 U.S.C. 2192 (b)

PROGRAMS:
- DoD Science and Engineering Education Panel
- Junior Science and Humanities Symposia
- Research and Engineering Apprenticeship Program (REAP)
- "Uninitiates" Introduction to Engineering (UNITE)
- Science and Engineering Apprentice Program (SEAP)
- International Mathematical Olympiad and Science and Engineering Fairs

Figure I-37. Historically Black Colleges and Universities/Minority Institutions

CENTERS OF EXCELLENCE:
- Training
  Morris Brown College—$750K annually
- Research in Information Sciences
  Clark-Atlanta University—$750K annually
- Advanced Fuel Cell and Battery Manufacturing Technology
  Illinois Institute of Technology—$2M annually
- Science, Math, and Engineering Education
  Contra Costa College—$500K annually

SINGLE INVESTIGATOR PROGRAMS AT:
16 investigators at 11 institutions—$50K to $110K annually
e.g. *University of Detroit–Mercy* — *Howard University*
North Carolina A&T State Univ. — *Illinois Institute of Technology*

COLLABORATIVE RESEARCH PROGRAMS:
- U.S. Army High Performance Computing Research Center
  Subcontractor-*Howard University*

16% of Army Academic Awards go to HBCU/MIs

Figure I-38. Army 6.1 Funding in Science, Mathematics, and Engineering Education

($K)

	FY94	FY95	FY96
Precollege	1559	1867	2312
Undergraduate	103	83	95
Graduate	1239	202	178
Postgraduate	410	436	623
Other	1278	1170	1170
Total	**4589**	**3758**	**4378**

Examples:
- NRC Postdoctoral Associates
- National Defense Science and Engineering Graduate Fellowship Program
- Cooperative Education Programs
- Army Summer Faculty Research and Engineering Program
- Army Summer Associateship for High School Science and Math Faculty
- Student Contractor Program
- Surplus Equipment Loan and Transfer

H. The Army Legacy

The Army Science and Technology Master Plan projects the development and maturation of technologies for the Army's future systems and system upgrades. Indeed, it is this transition of technology into affordable systems and capabilities which makes the science and technology program a sound investment. Over the last 50 years, Army R&D has developed and fielded a number of significant product and process technologies, some of which are highlighted in Figure I-39. Figures I-40 to I-42 highlight some of the S&T contributions to Army aviation, tanks, and howitzers. The impact of these technologies on military operations has been significant. Army S&T products have helped win the Cold War, Operation Just Cause, and Desert Storm. Beginning in the 1980s, past Army investments from basic science through subsystem components have made the U.S. leader in night vision capability (see Figure I-43). Today's investments will likewise lead to compact power for the 21st Century (see Figure I-44).

I. Conclusion

The Army Science and Technology Master Plan is approved by the Secretary of the Army and the Chief of Staff of the Army. It is our S&T roadmap for achieving Force XXI. This plan is provided to government, industry, and academia to convey the Army's science and technology vision, objectives, priorities, and corresponding investment strategy. This document is explicit, resource-constrained Department of Army guidance to drive funding priorities and the science and technology program as a whole. "Resource-constrained" means the program activities discussed in this document are funded in the FY 1997 Army Appropriation and the FY98 President's Budget (FY98-03). The schedules and projected technical accomplishments reflect this level of funding.

It should also be noted that laboratory and center Directors have sufficient flexibility, resources, and authority to initiate projects, explore promising avenues of research and development, and exploit opportunities as they are identified beyond those which are discussed

Figure I-39. Army R&D Accomplishments

1990	Hypertonic saline dexton effectively resuscitates after significant hemorrhage, and poses no hazard to renal function CORE-LOC concrete armor unit for breakwaters Full color thin film electroluminescent one million pixel flat panel display Composite hull for armored vehicles Produced enzymatically active human acetylcholinesterase using recombinant DNA techniques Airborne standoff minefield detection system Second generation FLIRs Food and drug administration licensure of halofantrine Insects for biological control of problem aquatic plants Rock rubble anti-penetration shielding Day/night adverse weather pilotage system (D/NAPS) Gene code in drug resistant malaria strains analogous to that in human cancer cells resistant to anticancer drugs Intrinsic chemical markers for food safety to validate the safety (i.e., sterility) of thermoprocessed particulate foods
1980	AIDS diagnostic and staging schemes published for wide usage Resin-based, non-toxic skin decontamination kit fielded Pretreatment, improved antitode and anticonvulsant therapy for nerve agent poisoning Ballistic-laser protective spectacles fielded High precision missile terminal imaging Mefloquine, antimalarial drug fielded All Composite Aircraft demonstrated Image processing Personnel selection, classification, and assignment for formation of volunteer Army Wire strike protection system fielded
1970	Reverse osmosis water purification fielded Frequency hopping radios Fiberoptics applications: Fly-by-light, FOG-M, communications Lightweight, flexible body armor Meals, ready to eat (MRE) High burn rate solid rocket fuel technology First practical tilt rotor system demonstrated Superlattice electronics First generation thermal imager fielded
1960	Meningitis vaccine developed Individual and vehicle ceramic armor Inertial surveying for field artillery demonstrated Freeze dried compressed foods introduced Fast Fourier transform developed Sulfamylon, an antibacterial cream, development for treatment of burns First starlight scope fielded Laser rangefinder Rubella virus (German measles) isolated Laser semiactive guidance invented and demonstrated
1950	Global standard for time measurement Photolithographic process for printed circuit boards First weather/communications satellites Solar cells for satellites Redstone rocket—Army first in space Turbine power for helicopter fielded Dehydration/freeze drying of foods made practical Mouth-to-mouth resuscitation developed Image intensifier scope T1-6A1-4V titanium alloy for aircraft developed
1940	Iodine tables for individual water purification First specific cure for typhoid fever First synthetic quartz ENIAC, first modern electronic computer First supersonic wind tunnel Atomic bomb fielded Helicopter first flown Engine for first American jet fighter Whole blood preservation Proximity fuze

Figure I-40. Aviation: Past and Future

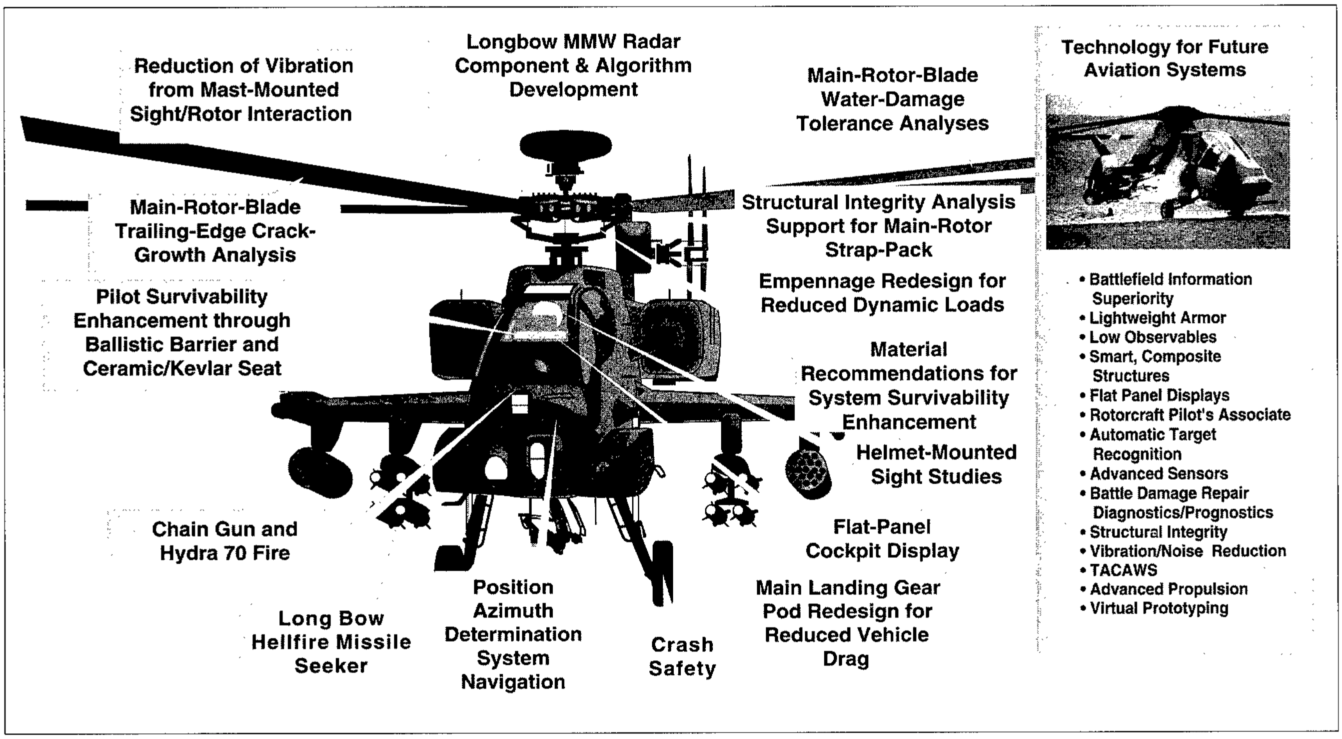


Figure I-41. S&T Contributions to Abrams

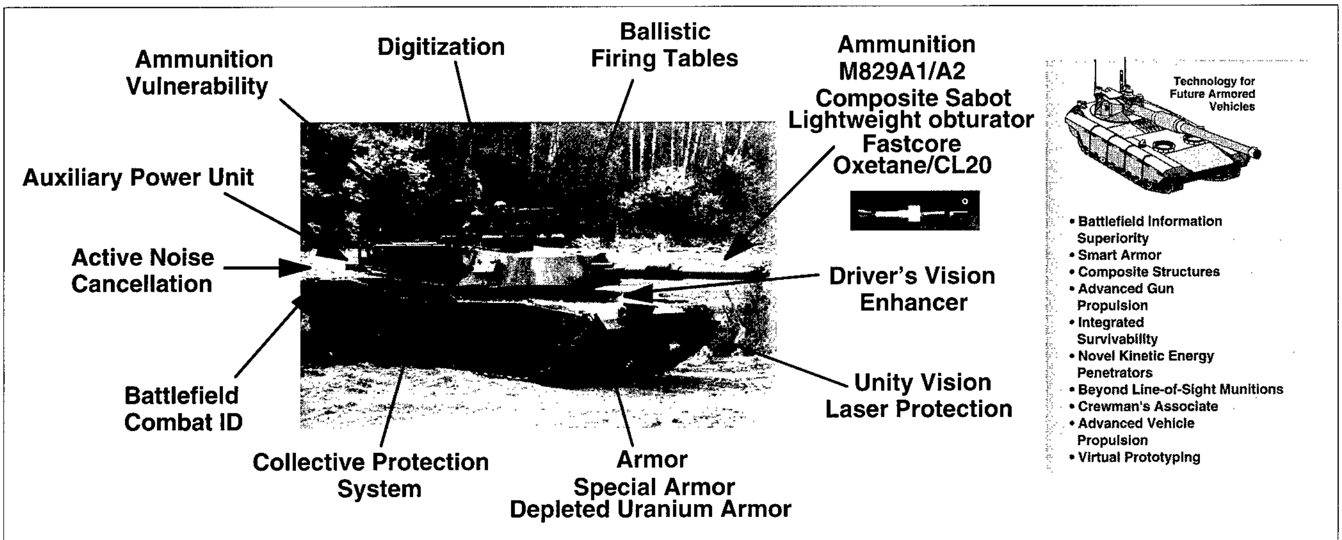


Figure I-42. Howitzers: Past and Future

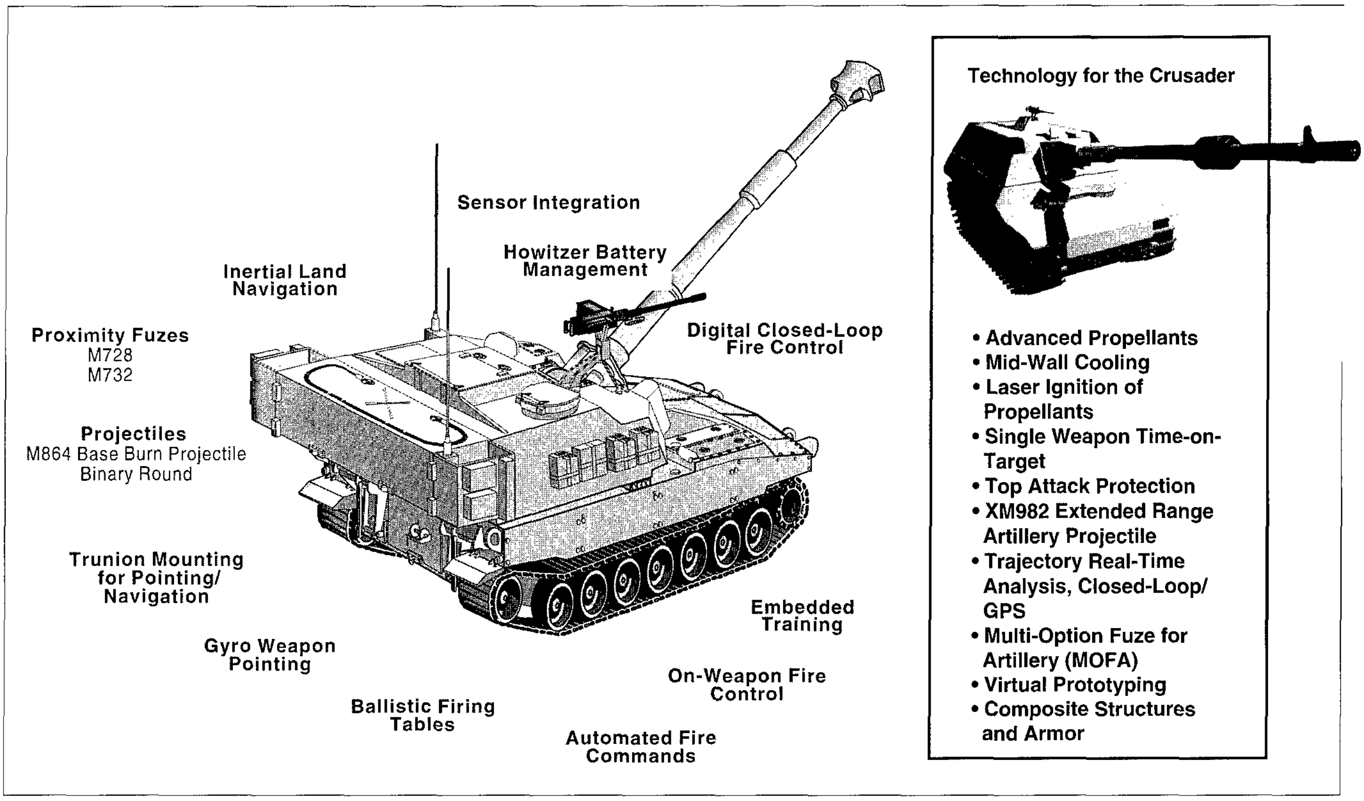


Figure I-43. Evolution of 2nd Gen FLIR Technology

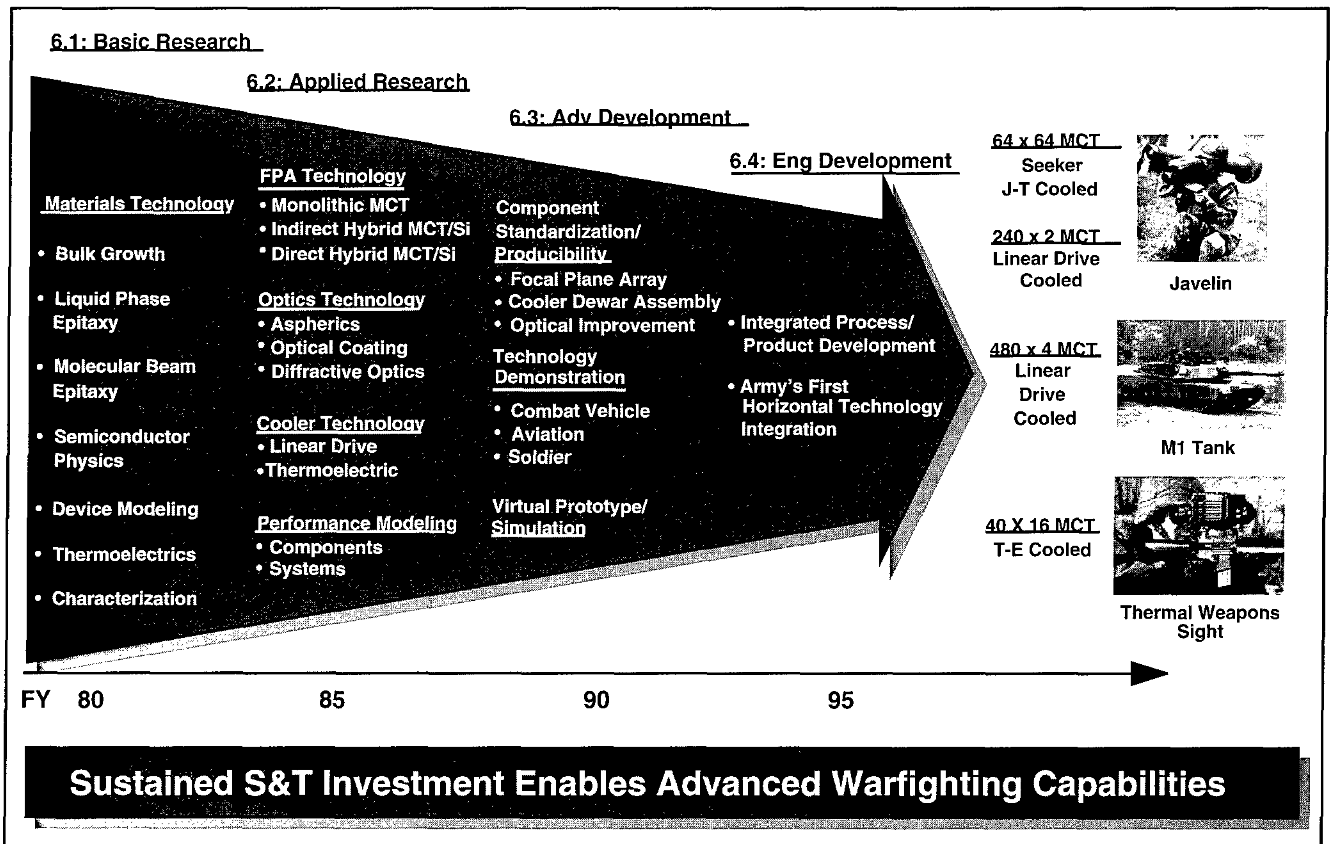
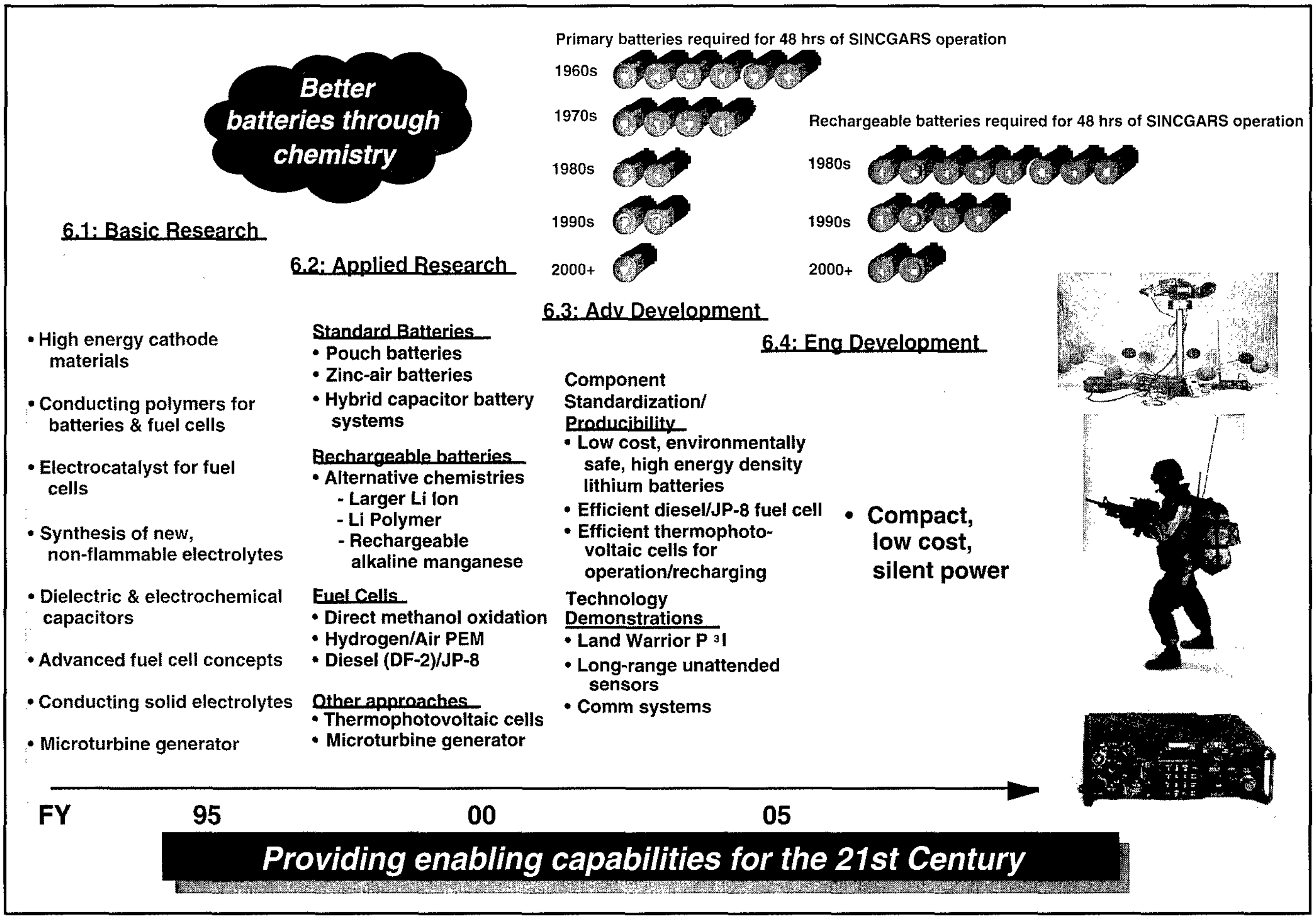


Figure I-44. The Future of Compact Power Technology



in this document. Budget reductions, however, continue to erode this flexibility so essential to technical discovery and support to the acquisition and field commanders. The Army's science and technology strategy and plan include support to the Defense Technology Area Plan, JCS Future Warfighting Capabilities, Project Reliance, and cooperation with our allies to pursue common goals.

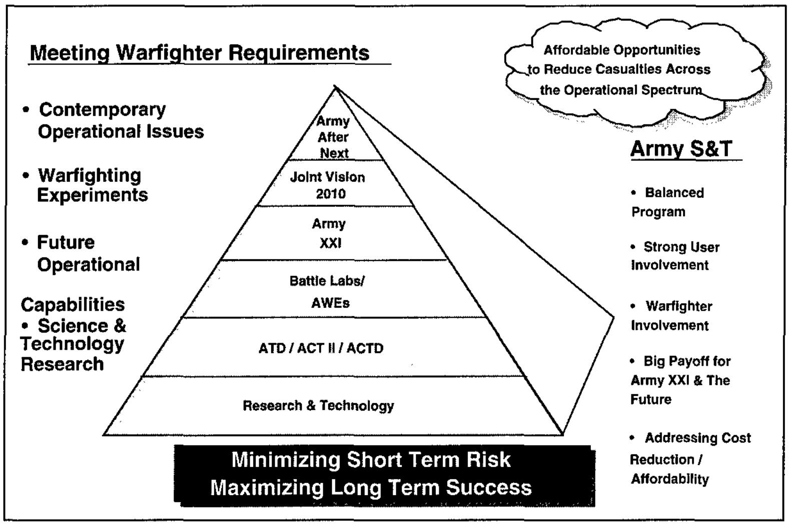
Technological superiority is essential if a smaller Army is to be able to successfully engage in a wide variety of future conflicts with minimum casualties. With continued support, the Army S&T program will ensure our affordable technological superiority, avoid technological surprise, and provide us with revolutionary warfighting capabilities for the next century (see Figure I-45 and Figure I-46).

Figure I-45. S&T Doing More for the Warfighter With Less Resources

S&T Now Includes:

System-of-Systems Capability Demos
ACTDs (Large Scale Field Exercises and Residual Capabilities)
Simulation Technology to Support How-to-Fight Demos
Concepts for Battle Labs (ACT II)
Industrial Partnerships (NAC and NRTC)
Federated Labs (6.1)
Environmental Technology
Producibility (Integrated Product and Process Design)
Support to Advanced Warfighting Experiments
Technology for Horizontal Technology Integration
More Complete Technical Risk Reduction
Acquisition Reform via Fast Track (straight to EMD)

Figure I-46. S&T—Focused On the Warfighter



America's Army exists to fight and win our Nation's wars. Our Army today is ready to accomplish this and any other task required. The Army has a vision that enables us to sustain this essence while accommodating enormous change with balance and continuity. Today's soldiers benefit from past commitments to a robust S&T program. Tomorrow's soldiers deserve no less.

"We are not the only nation with competence in defense science and technology. To sustain the lead which brought us victory during Desert Storm...recognizing that over time other nations will develop comparable capabilities, we must...invest in the next generation of defense technologies."

William J. Perry, Secretary of Defense

CHAPTER II

Science and Technology Integration With Army XXI Requirements Determination

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CHAPTER II

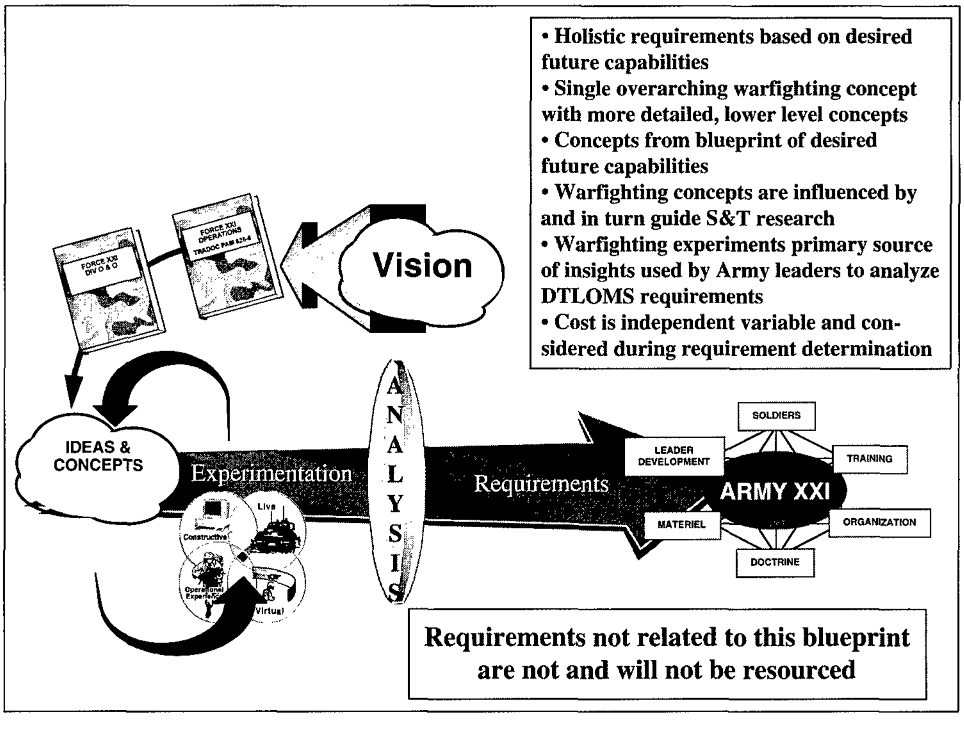
Science and Technology Integration With Army XXI Requirements Determination

A. Requirements Determination

For the past three years, the Army has explored new ways to determine requirements. No longer can we afford, fiscally or otherwise, to determine requirements based on deficiencies identified between our capabilities and those of the former Soviet Union and the Warsaw Pact.

We now determine requirements more holistically based on desired Joint and Army capabilities versus known deficiencies. We are not trying to perfect yesterday's shortfalls; rather, we are anticipating tomorrow's required capabilities. This is being driven by warfighting concepts focused on the future and experimentation in our battle labs to discern viable requirements. Our new way of doing business recognizes that requirements can evolve from several means: TRADOC schools, battle labs, other MACOMs, the Force XXI Joint Venture, and field commanders. All employ variations of the same process but with different levels of senior leader involvement. More leader involvement reduces requirements decision timelines. Ultimately though, TRADOC school commandants define, document, and defend DTLOMS requirements. (See Figure II-1.)

Figure II-1. A New Way of Doing Business



The requirements determination process begins with a holistic future warfighting concept. This concept is formed from a wide variety of inputs, including the national security and military strategies, lessons learned from recent operational experiences, and future conflict scenarios. Additionally, the concept is influenced, but not driven, by an appreciation of future science and technology (S&T) possibilities. This overarching concept is the basis for operations and functional concepts addressing the full spectrum of Army operations and functions. Together, the warfighting concepts are the Army's "blueprint" for determining DTLOMS requirements across the combined arms and services team. Requirements not related to this blueprint are not and will not be resourced.

No requirement is determined in isolation. Senior leaders make requirements decisions based on an understanding of all potential requirements, cost goals, and their impact on the operational force. We will not abandon the search for potential "silver bullets," but we can no longer expect performance at any cost—we just cannot afford everything we want. With cost as an independent variable, the preferred solution will include an affordable life cycle cost.

Determining requirements is just the first of many steps or activities leading to the desired future warfighting capability. After the TRADOC Commander approves them, organization, materiel, and soldier requirements are sent to DA for final action. After this, the requirements are resourced, solutions are selected, and then capabilities are fielded. TRADOC retains defined doctrine, training, and leader development requirements for resourcing and solution development.

1. Concept Development

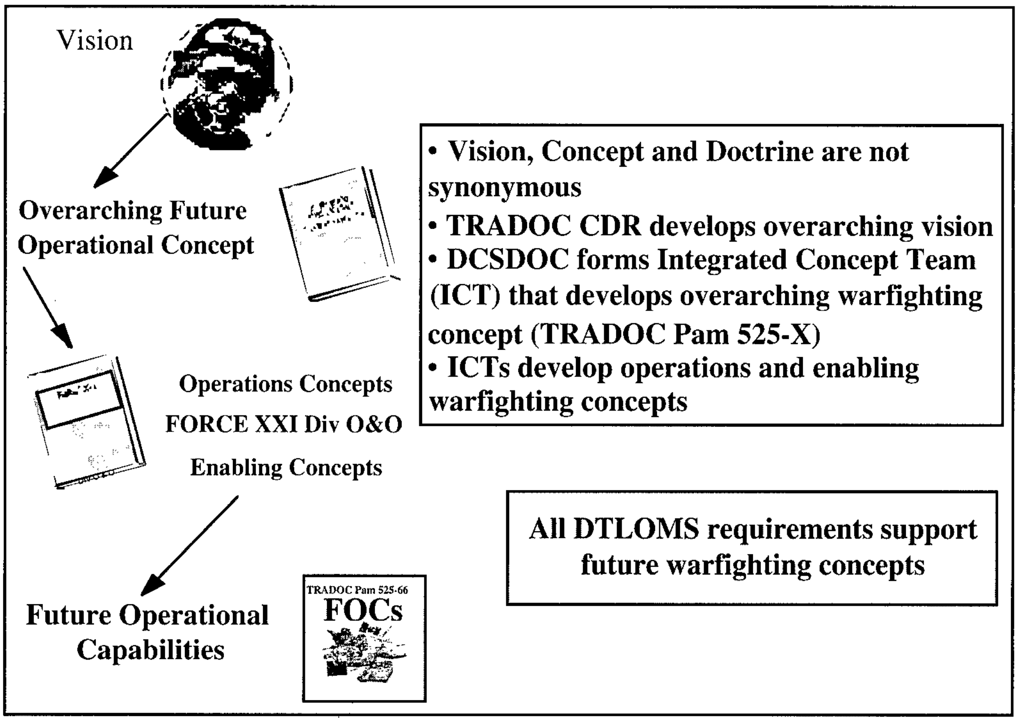
The military community often uses the terms "vision," "concept," and "doctrine" interchangeably, but they are not synonymous. A "vision" is a rudimentary abstract description of a desired endstate. A "concept" translates a vision or visions into a more detailed, but still abstract description of some future activity or endstate. "Doctrine" is a body of thought that comprises the fundamental principles by which military forces guide their actions in support of objectives. It represents consensus on how the Army conducts operations today. Visions and concepts generate questions about the future while doctrine provides answers about today. Integrated multidisciplinary teams produce concepts. Doctrine evolves as questions about concepts are answered or as concepts are validated through analyses, experiments, exercises, or actual operations.

The TRADOC Commander develops the Army's future warfighting vision. It is a holistic description of desired Army capabilities as seen during a commander's recon from a "mountain top" in the distant future. Because of the lack of a clearly defined adversary, warfighting experience and the national security and military strategies are most influential to vision development, with science and technology opportunities providing a frame of reference. (See Figure II-2.)

An Integrated Concept Team (ICT) formed by the TRADOC Deputy Chief of Staff for Combat Developments (DCSCD) translates the future warfighting vision into an overarching warfighting concept. This concept is a more detailed description of Army capabilities as seen during a "staff ride" from the same mountain top visited by the TRADOC Commander. In addition to codifying the future warfighting vision, the overarching warfighting concept reflects more direct linkages to the National Military Strategy (NMS), the Defense Planning Guidance (DPG), Joint Vision, the Chairman, Joint Chiefs of Staff Capabilities Plan, the various Commanders in Chief Integrated Priority Lists (CINC IPL), the Joint Warfighting Capability Assessment (JWCA), the Army Long-Range Planning Guidance (ALRPG), The Army Plan (TAP), and the Army Modernization Plan (AMP). In so doing, the overarching warfighting concept becomes the primary reference for all other concept development activities. The Army's overarching warfighting concept is documented in TRADOC Pamphlet (TP) 525-5.

Since the overarching warfighting concept provides a holistic, macro-level description of the future Army, it is augmented by more detailed operations and functional concepts, which describe the full range of interdependent and related future Army capabilities from a variety of perspectives and levels. HQ TRADOC, school commandants, and selected non-TRADOC leaders form ICTs to produce these concepts. All warfighting concepts begin as intellectual products which are further developed through

Figure II-2. Concept Development



constructive analysis and experiments. This allows them to be defined in greater detail, refined, and substantiated as a relevant framework for requirements determination. The TRADOC Commander approves all concepts. Examples include: Division Operations, Modularity, Information Operations, Battlefield Visualization, Non-Lethal Operations, Space-Support to Land Warfare.

A key function to be matured at HQ TRADOC is a holistic analytical constructive ability to allow an annual, or biennial, review of future force concepts and designs. This will require Army-wide acceptance of a series of constructive simulations, the sum of which depict a reasonable estimate of the Total Army Force required at any point throughout the program period. This will provide a forum for review of all "new ideas" that have emerged during the year with the intended outcomes being a holistic picture of a force and how it might fight and dismissal of obviously "bad" concepts.

Concept development usually leads to S&T research or experimentation. Concept development occasionally produces a compelling idea that can be defined as a DTLOMS requirement. In those cases, the S&T and experimentation phases are bypassed. Early—accurate—requirements definition is the ultimate goal of our requirements process.

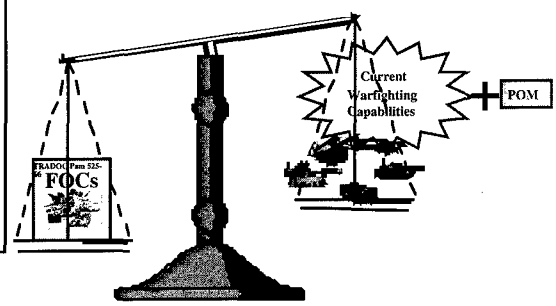
2. Future Operational Capabilities

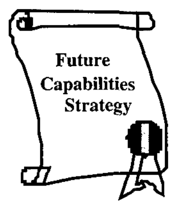
A summary of desired future operational capabilities described in concepts approved by the TRADOC Commander will be provided in TP 525-66, Future Operational Capabilities (formerly called Operational Capability Requirements) (see Volume II, Annex C). This document will be the control mechanism for requirements determination activities. It is the basis for a holistic appraisal of current and desired future capabilities which produces a future capabilities strategy. This strategy provides the authority to conduct studies and warfighting experiments to better understand desired capabilities and the means to achieve them. (See Figure II-3.)

In the past, the requirements determination process made it virtually impossible to cross-reference future capabilities. TP 525-66 will open up the requirements determination process to all players and will enable horizontally integrated DTLOMS requirements determination across the combined arms team. This will be especially useful to materiel developers, providing an unclassified reference to guide independent research and development (IR&D) and facilitate better horizontal technology integration (HTI) throughout future systems.

Figure II-3. Future Operational Capabilities

- Described in approved warfighting concepts
- Prioritized in TP 525-66
- Evolve from Operational Capability Requirements (OCR)
- TP 525-66 control mechanism for requirements determination activities
- Holistic appraisal of current and desired future capabilities produces future capabilities strategy





Future capabilities strategy provides basis to conduct studies and warfighting experiments

3. Science and Technology Support to Requirements Determination

The Army S&T program is the breeding ground for innovative technological warfighting insights. Moreover, the S&T program supports our goal of rapid requirements determination by recognizing that there are different research timelines associated with every technology, e.g., it does not impose the same timelines on software development as it does for precision guided munitions.

A series of reviews of current and proposed S&T activities guide focused research. The first is a TRADOC annual assessment of all proposed Army-funded S&T projects. It is conducted based on an appreciation of current capabilities, ongoing S&T activities, and their applicability to the future capabilities described in TP 525-66. (See Figure II-4 and Section B of this chapter.)

TP 525-66 also guides IR&D. By providing the private sector an unclassified, descriptive list of desired future capabilities, the Army is able to tap into a wealth of information and new ideas on different means to achieve those capabilities. The Army encourages industry to share these ideas with appropriate combat or training development organizations. A special program—the Advanced Concept and Technology II (ACT II) program—provides "seed money" to actually demonstrate the various ideas.

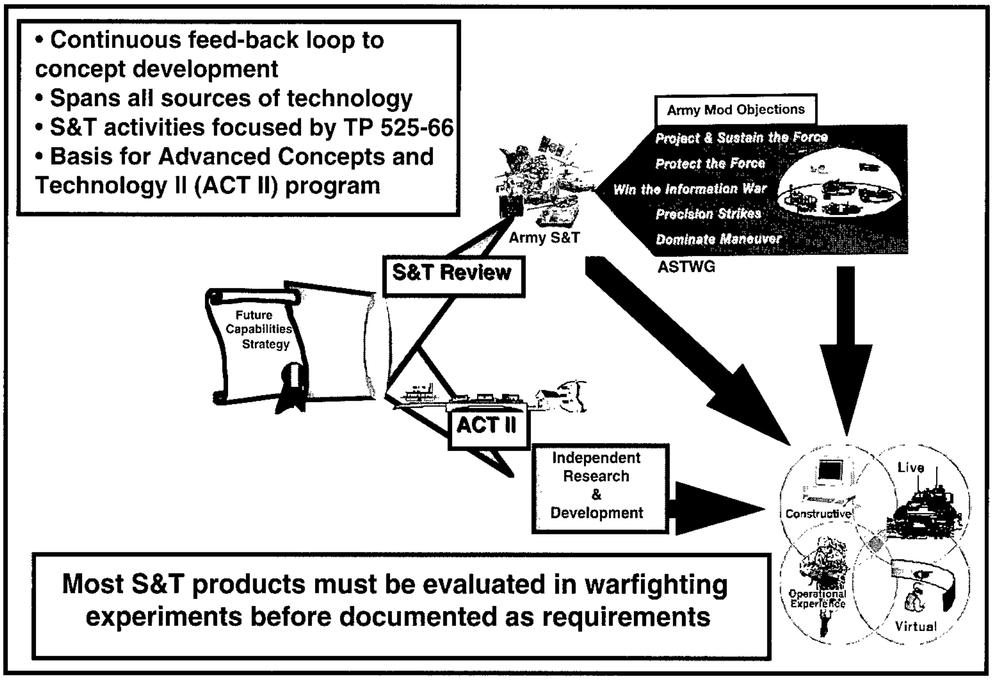
4. Warfighting Experimentation

Warfighting experiments are the heart of the Army's warfighting requirements determination process. Progressive and iterative mixes of high fidelity constructive, virtual, and live simulations using real soldiers and units in relevant, tactically competitive scenarios provide Army leaders with future operational capability insights.

This aspect of the new requirements process is often overlooked or misrepresented. "Warfighting experiment" is not a new name for test and evaluation. While testing may occur in an experiment, we conduct experiments to gain understanding about some aspect of future warfighting, not to just measure the performance of new doctrine, training, leader development, organization, or materiel. Capability insights are "way points" used to plot the Army's future course.

There are a wide variety of warfighting experiments. All begin with formal hypotheses derived from contemporary operational issues, warfighting concepts, or S&T research. The hypotheses may relate to any of the DTLOMS domains. New or changed doctrine, organizations, and materiel generate the majority of experiment hypotheses. However, training, leader development and soldier issues may also drive independent experiments. Regardless of what initiates an experiment, it becomes

Figure II-4. Science and Technology Support



a training and leader development experience for the entire Army as we experience some aspect of future warfighting.

The principal role of the battle labs is to plan and conduct warfighting experiments. Working with the concept proponent and the TRADOC Analysis Center (TRAC), battle labs develop hypotheses and then prepare detailed experiment plans that describe objectives, measures of performance, measures of effectiveness, participants, milestones, data collection, and resources. This is a change from the last three years when battle labs were much more involved with other aspects of requirements determination.

TRAC, assisted by other organizations as needed, analyzes the results of every experiment. TRAC analyses, and recommendations from actual experiment participants, form the basis for the final experiment report. The experiment proponent can choose to discard the hypotheses in their current form, continue to experiment with the same or modified hypothesis, define DTLOMS requirements, or recommend rapid acquisition and fielding.

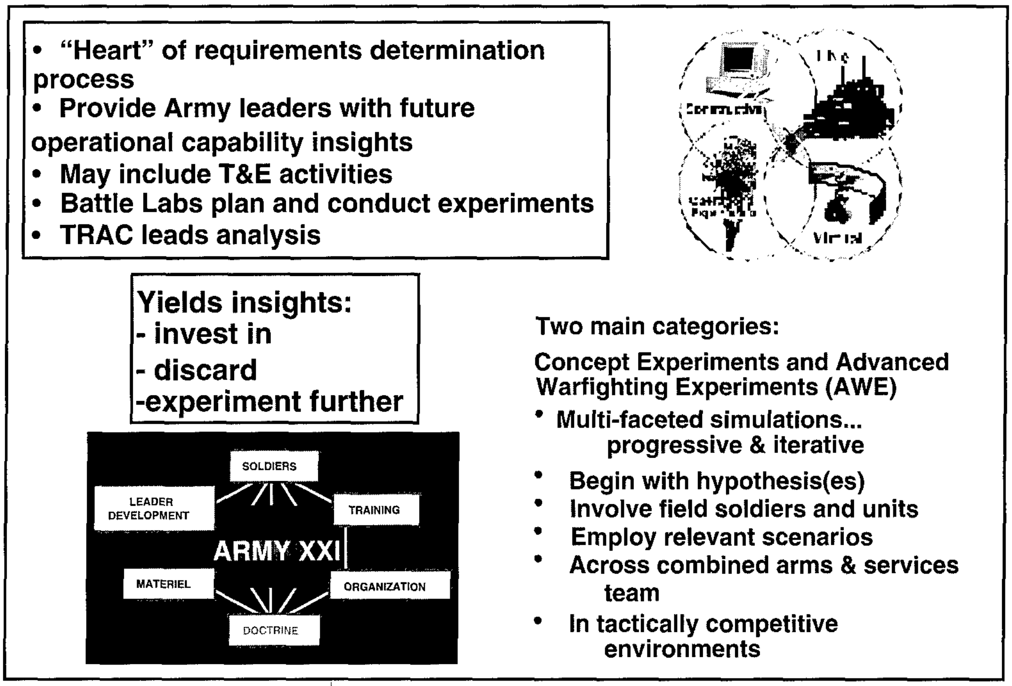
Depending on the nature of the experiment, the Army's Operational Test and Evaluation Command (OPTEC) may also be involved with the experiment design and execution. When possible, this facilitates concurrent statutory test and evaluation which potentially reduces fielding times.

There are two main categories of warfighting experiments—concept experiments and advanced warfighting experiments (AWE). The overwhelming majority are concept experiments pertaining to individual operations or branches. They are the means to "model-experiment-model" possible requirements and are the building blocks in the "progressive and iterative mix" of simulations. Additionally, they are usually small enough to support the detailed planning and data collection required by the test and evaluation communities. A concept proponent conducts the experiment or requests a battle lab to sponsor it. They either resource it in-house or request resources from the TRADOC DCSCD Concept Experimentation Program (CEP).

Experiments that are focused on a major increase to warfighting capability across multiple branches are part of the AWE program. Any of the concept proponents recommends the experiment, the TRADOC Commander sponsors it, and the Chief of Staff, Army, approves and resources it. (See Figure II-5.)

Today, most warfighting experiments employ live simulations—soldiers and units in field environments. However, live simulations are very expensive, and if they involve new materiel may occur late in the materiel development cycle. Future warfighting experiments will use a comprehensive suite of reconfigurable simulators and simulations in addition to live simulations.

Figure II-5. Warfighting Experiments



Distributed interactive simulations (DIS) connected by the Defense Simulations Internet (DSI) will create a synthetic theater of war (STOW) that enables Army leaders to quickly model, evaluate, and change different requirements from any of the DTLOMS domains. Thus, future warfighting experiments will leverage relatively low-cost models to explore requirements across the DTLOMS spectrum, reserving expensive field exercises for the final defining event in the requirements determination process.

Warfighting experiments provide the Army an unsurpassed means to understand future warfighting requirements. Planned and executed with the entire combined arms team and appropriate other service elements, warfighting experiments open "windows to the future." Understanding the costs and benefits of change across the force and in all domains allows us to "maintain the edge" and conserve resources at the same time.

5. Contemporary Operational Issues

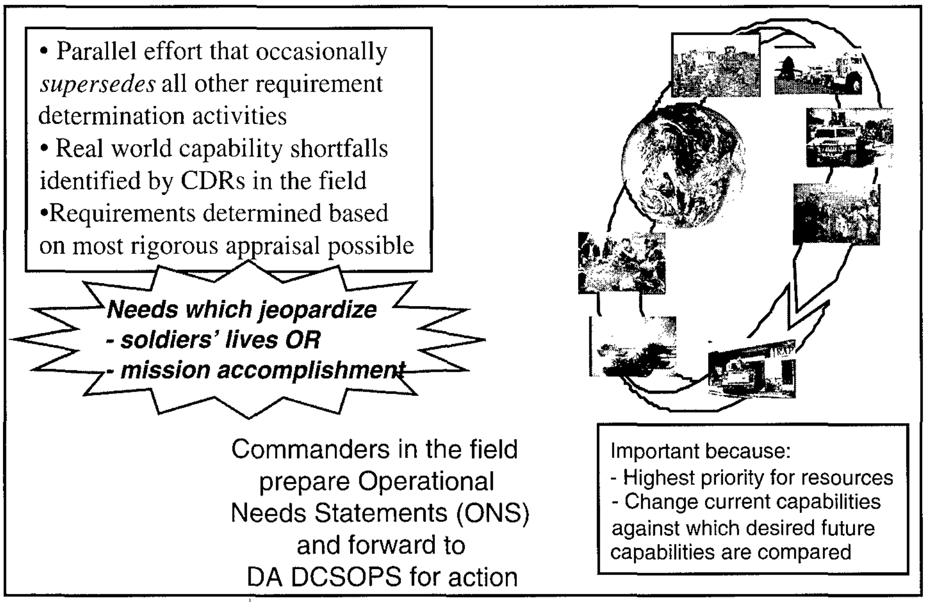
It is important to understand a parallel effort that occasionally supersedes all other requirement determination activities. Contemporary operational issues—warfighting needs of soldiers and units engaged in real operations somewhere in the world—take precedence over future requirements. These issues are addressed by a microcosm of the larger requirements determination process, with some of the same teams that are involved with future requirements quickly refocused to address the contemporary issues.

Commanders in the field identify critical operational needs—ones that jeopardize soldiers' lives or a unit's ability to accomplish assigned missions—and forward them to DA DCSOPS via an operational need statement (ONS) in the most expeditious manner possible. (See Figure II-6.)

The DA DCSOPS reviews the ONS and determines the appropriate response. Materiel needs that already have approved requirements documents or require urgent, out-of-system reaction to preserve life will be forwarded directly to the materiel development community. TRADOC will be informed of such actions and will assist resolution of the need by all possible means. Need requests not deemed urgent by DA DCSOPS will be forwarded to TRADOC for routine action.

Clearly, work on contemporary operational issues impacts requirements determination. Contemporary operational issues have the highest priority for already scarce resources and divert attention away from future needs. More importantly, contemporary operational issues modify our current capabilities, affecting the amount of change needed to achieve desired

Figure II-6. Contemporary Operational Issues



future operational capabilities. Our challenge is to address the most critical issues with all possible means and speed but not become sidetracked by unimportant special interest projects.

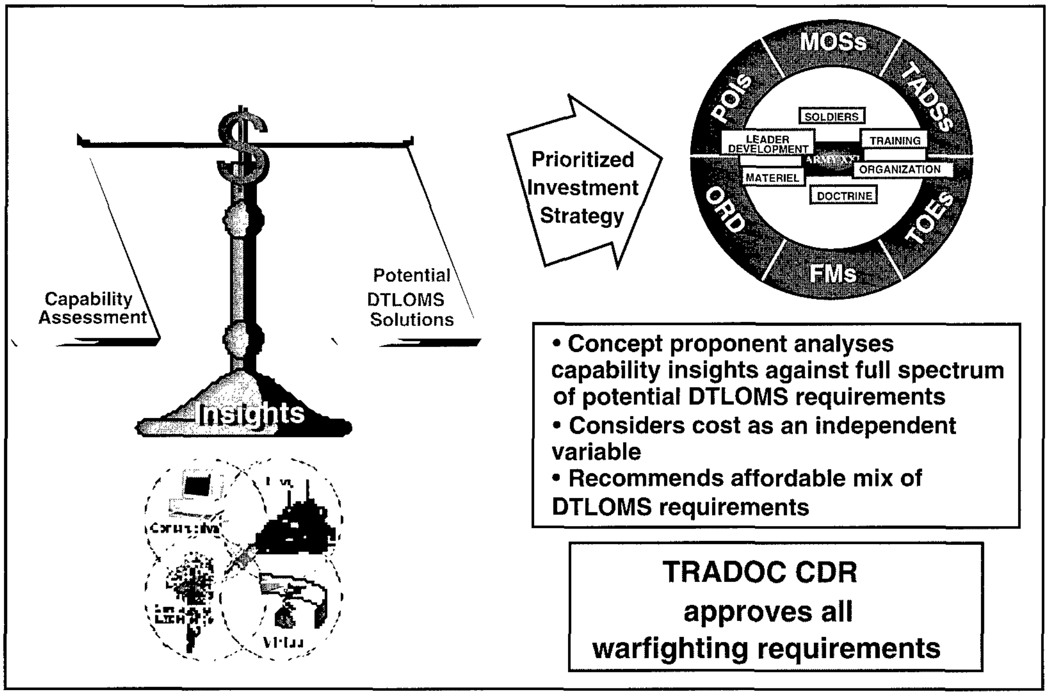
6. From Insights to Requirements

Concept development, S&T technology development, warfighting experimentation, and contemporary operational issues provide DTLOMS insights. The insights describe different means to achieve future operational capabilities. Before they can be translated into requirements, the insights must be integrated and analyzed by the concept proponent. The goal of this analysis is to determine the most effective, timely, and least costly means to achieve the future operational capability.

Doctrine insights pertaining to the future operational capability, down to TTP levels, are analyzed first. If doctrine changes provide the operational capability, the TRADOC Commander approves them and forwards them to the operational force. (See Figure II-7.)

If doctrine insights do not provide the operational capability, the same steps are used to analyze in order: training, leader development,

Figure II-7. From Insights to Requirements



organizational design, and, finally, materiel. This review sequence results from the requirement and solution development costs and timelines of each domain. With cost as an independent variable, the least costly and most rapid changes are considered first. Moreover, it reflects the impact that changes made in one domain have on the others. Changes made in domains at the end of the list have a reverse "cascade" effect generating changes in most of the preceding domains.

7. Warfighting Requirements

Requirements occur in all of the Army domains: doctrine, training, leader development, materiel, organizations, and soldiers. The following are examples of how each domain documents requirements.

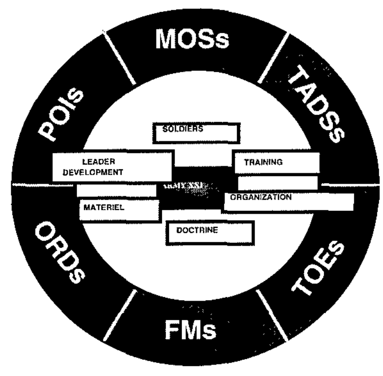
Doctrine requirements are changes or additions to any of the Army's fundamental principles that guide operational forces. These principles range from TTP to Field Manual 100-5, Operations. School training and doctrine directorates are responsible for preparing doctrine requirements and forwarding them to HQ TRADOC for approval. The TRADOC Deputy Chief of Staff for Doctrine maintains a list of all doctrine requirements in the Doctrine Literature Master Plan (DLMP). The TRADOC Commander prioritizes and resources the DLMP based on overall TRADOC mission essential tasks. (See Figure II-8.)

Training and leader development requirements are changes or additions to any of the Army's training or professional development programs. These range from institutional training conducted at TRADOC schools to individual self-development and unit training programs conducted in the field. School training and doctrine directorates are also responsible for preparing training requirements and forwarding them to HQ TRADOC for approval. The TRADOC Deputy Chief of Staff for Training (DCST) maintains a list of all TADSS requirements in the Combined Arms Training Strategy (CATS). The TRADOC Commander prioritizes and resources CATS based on the overall TRADOC mission essential tasks.

Organization requirements are changes or additions to any of the Army's tables of organization and equipment (TOE). These range from modifying the numbers or types of equipment in a current organization to documenting an entirely new organization. School combat development directorates and other combat development organizations are responsible for preparing organization requirements and then forwarding them to HQ TRADOC for approval. The TRADOC DCSCD reviews, integrates, and prioritizes organization requirements and then forwards them to the Army DCSOPS

Figure II-8. Warfighting Requirements

- Occur in all DTLOMS domains
- Determined holistically with cost as an independent variable
- Doctrine, Training and Leader Development requirements translated into solutions by TRADOC
- Organizations, Materiel & Soldier requirements sent to DA for solution development by other MACOMs



	TRADOC	TRADOC	DA (OPS/PER)	AAE/PEO/PM
D	Reqmt	Solution		
T	Reqmt	Solution		
L	Reqmt	Solution		
O	Reqmt		Solution	
M	Reqmt			Solution
S	Reqmt		Solution	

DTLOMS *requirements:*
- Interrelated
- *Not* worked in isolation

for final action. A list of approved TOEs is maintained in the Structure and Manpower Allocation System (SAMAS) Army Master Force (MFORCE) and are resourced based on overall Army Force Package needs.

Materiel requirements are changes or additions to any of the Army's families of weapons, support systems, or TADSS. They range from modernizing existing materiel through parts replacement; major product improvements of existing materiel; one for one replacement of old materiel with new materiel designed to do the same job; to completely new families of materiel designed to do something that has not been done before. School combat development directorates, training and doctrine directorates, or other combat development organizations are responsible for preparing materiel requirements—operational requirements documents (ORDs)—and then forwarding them to HQ TRADOC for approval. The TRADOC DCSCD or DCST, as appropriate, reviews, integrates, and prioritizes ORDs and then forwards ORDs approved by the TRADOC Commander to the DCSOPS for final action by the milestone decision authority. Approved ORDs are added to the Catalog of Approved Requirements Documents (CARD) file and are resourced based on the priorities established in the Army Research, Development and Acquisition Plan.

Soldier requirements are changes or additions to the Army's military occupational specialty (MOS) structure. These range from changes in the numbers of soldiers needed in a MOS to creation of an entirely new MOS and identifying the skills desired of these soldiers. Branch proponency offices are responsible for preparing soldier requirements and forwarding them to the TRADOC DCST. He in turn forwards them to the Army Deputy Chief of Staff for Personnel, who adds them to the Military Occupation Classification and Structure Plan and resources them based on overall Army Force Package needs.

All of these warfighting requirements relate to each other in countless ways. They must not be determined in isolation.

8. Managing Requirements Determination

The requirements development process is only as effective as the people who are involved with the program. Integrated concept teams representing all elements of the Army, appropriate joint and coalition forces, industry, and academia are the principal means to ensure the right people are involved. However, no organization can afford to have its personnel away from normal duties all the time. Managing the ICT process is just as important as getting the right people involved. (See Figure II-9.)

The ICT objectives must be clearly defined with a reasonable amount of time allocated to achieve them. Its approach should not be constrained in any way. Full use of the various

Figure II-9. Integrated Concept Teams (ICT)

<u>What:</u> A gathering of multidisciplined people

<u>Purpose:</u> Develop a concept or determine capabilities/ requirements

<u>Key is ***simplicity*** and ***flexibility***:</u>

- ICT may be
  - created by CGs, DCGs, or DCSs
  - formal (chartered) or informal
  - living or have an event/product to conclude
- Commandant must delineate lead for school level ICT
- CG, TRADOC should be informed of initiation and expected end date
- General announcement should be made upon completion

electronic media is encouraged to include electronic mail, video teleconference, DIS, and reconfigureable simulators.

The importance of this multidisciplinary approach to requirements determination cannot be overstated. We must rid ourselves of overly bureaucratic procedures that stifle creativity and reduce responsiveness. Joined together in ICTs, the representatives of otherwise disparate organizations provide the Army an unparalleled means to "see" the future. (See Figure II-10.)

B. Science & Technology Integration With Requirements

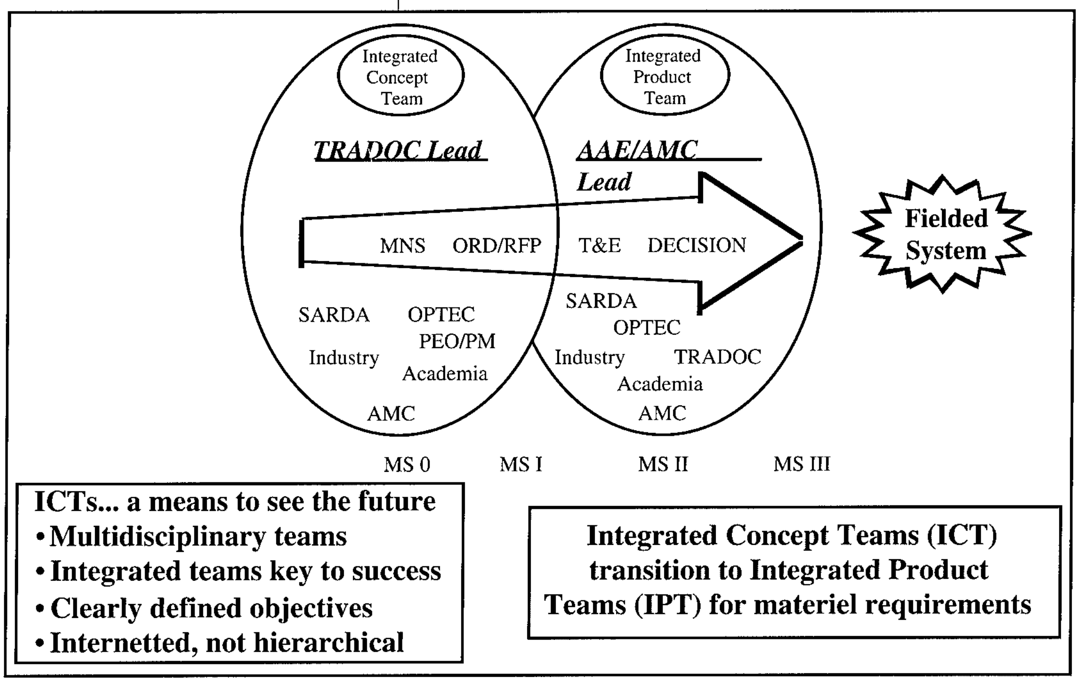
TRADOC's role in the Army's Science & Technology program is clearly defined. As the originator of warfighting requirements for the Army, TRADOC uses three tools to help focus the S&T communities' support the Army's requirements: the S&T review, the STO review, and the ACT II program. Although separate but concurrent, these tools help to focus the Army's S&T efforts to best meet the requirements TRADOC determines. The mechanism the TRADOC community uses to evaluate the current S&T work effort is Future Operational Capabilities (FOC) statements.

1. Future Operational Capabilities (FOC)

FOCs are statements of an operational capability required by the Army to achieve the ideas articulated in the hierarchy of concepts (TP 525 series) and to maintain military dominance over the operational environment in which it will be required to operate. FOCs are employed in the TRADOC Science & Technology (S&T) and the Science & Technology Objective (STO) Reviews as the measure for assessing the warfighting merits of individual science and technology efforts. FOCs guide the Army's Science & Technology investment. Materiel developers and industry use FOCs as a reference to guide independent research and developments and facilitate horizontal technology integration (HTI). FOCs are used within the Army Science and Technology Master Plan (ASTMP) process to provide a warfighting focus to technology base funding.

TRADOC Pamphlet 525-66, Future Operational Capabilities, is the control mechanism for requirements determination activities. It compiles and summarizes the desired future operational capabilities described in TRADOC approved concepts. TP 525-66 will

Figure II-10. Managing Requirements Determination



be the basis for conducting studies and warfighting experiments.

2. Science & Technology (S&T) Review

TRADOC conducts an annual (December-April) review of all Army 6.1, 6.2, and 6.3 S&T work efforts. The purpose of the review is to give the combat developer an opportunity to review and assess the relevance of the S&T work efforts to the warfighters' concepts. It also provides feedback to the materiel developers on the relative merits of each S&T work effort. The results from the S&T review will be used by the combat developer to identify potential Science and Technology Objectives (STO) candidates. It also provides information on perceived shortfalls and redundancies in the Army S&T work efforts.

3. Science & Technology Objectives Review

TRADOC holds an annual Science and Technology Objectives (STO) Review. The STO review provides the forum for the user and developer communities to vote on the warfighting and technical merit of each proposed STO. The STO review provides the follow-on mechanism to the S&T review that further defines and aligns users requirements and the materiel developer efforts. The STO review will provide one of the necessary links that connects the complete S&T Cycle. The results of the STO review is a 1 to n listing of the candidate STOs.

4. Advanced Technology Demonstrations

STO review provides the basis for the construct of Advanced Technology Demonstrations (ATD). TRADOC participates in the Advanced Technology Demonstrations via Battle Labs and Directorate of Combat Developments (DCDs). TRADOC and the Materiel Developer jointly develop a demonstration plan with agreed upon exit criteria to execute the ATD. ATD management plans are briefed to the Council of Colonels prior to approval at the Army Science and Technology Working Group (ASTWG). ATDs are resource intensive and provide the medium to conduct troop interaction with mature technologies. ATDs have provided significant contributions to the soldier(s) on the battlefield. Battle Lab Integration, Technology, and Concepts Directorate (BLITCD) serves as the primary coordinator for all ATDs.

5. Advanced Concepts and Technology II (ACT II) Program

The ACT II program was initiated in 1994 to give industry direct access into the battle labs to streamline materiel acquisition and help provide warfighters overmatch capabilities. ACT II competitively funds industry to demonstrate their advanced technologies, prototypes, and non-developmental items having the greatest potential to fulfill warfighting requirements. Demonstrations are conducted for the battle labs in 12 months or less.

The battle labs develop topics to be solicited via a BAA based on the results of the S&T and STO review processes. These reviews identified gaps and shortfalls in the S&T efforts. Those FOCs lacking Army S&T work efforts which can potentially be addressed by industry are selected for funding.

6. Summary

These concurrent evaluations of the Army's S&T efforts provide an overlapping assurance that the materiel developers stay focused on the warfighting requirements of the future. They provide a means by which efforts can be validated or refocused, duplication can be eliminated, and gaps can be filled.

C. Developing Army XXI Requirements

1. Characteristics of Force XXI Operations

a. Multidimensional

Force XXI will operate in an expanded battlespace. This battlespace goes beyond the traditional physical dimensions of width, depth, and height. It includes portions of the electromagnetic spectrum. This extends beyond the physical boundaries of the division through its communications and digital connectivity to other Army, Joint, and Coalition elements, even reaching back to CONUS from the Theater of Operations. Battlespace will also be defined by the human dimension; this includes not only soldiers and leaders, but also the civilian population in which operations are being conducted, citizens and families in the United States, and the peoples of the world. Finally, time is a dimension of battlespace that must be mastered. This concept seeks to seize and exploit the initiative to set the tempo of a battle, not just acting faster than the enemy, but acting at that speed which is best for execution of the friendly plan. (See Figure II-11.)

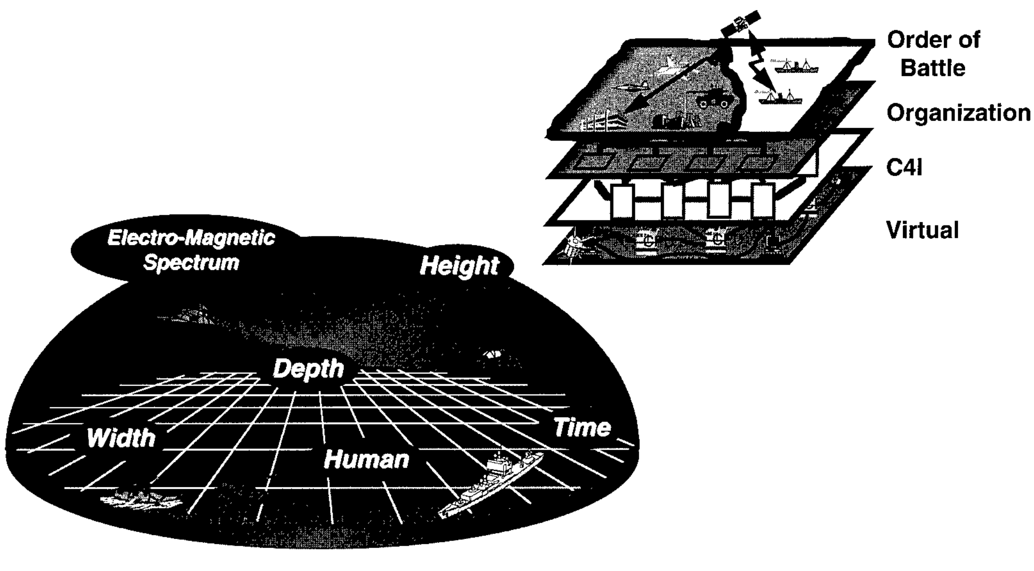
Battlespace will generally be framed by METT-T and largely shaped by corps or Joint Task Force (JTF) operations. This shaping includes not only the application of fires and combat power, but also deception, PSYOPS, civil affairs, host nation support, sustainment, intelligence, and reinforcement of existing terrain and infrastructure.

b. Precise

Force XXI Operations are characterized by synchronized attacks throughout the battlespace on units and targets which have been subjected to earlier, condition setting attacks to enhance their vulnerability. Such decisive operations require great precision. Precision in decisive operations is enabled by three emerging capabilities. First, digitization will provide soldiers and leaders at each echelon the information required for making informed decisions. Second, a full suite of multi-spectral strategic, operational, and tactical sensors linked to analytical teams will fuse combat information into situational awareness across the battlespace with greater clarity than ever before. Lastly, simulations will enable Army elements to be tailored based on emerging situation/crisis, plan operations based on METT-T, and wargame and rehearse those operations yielding precision in execution. (See Figure II-12.)

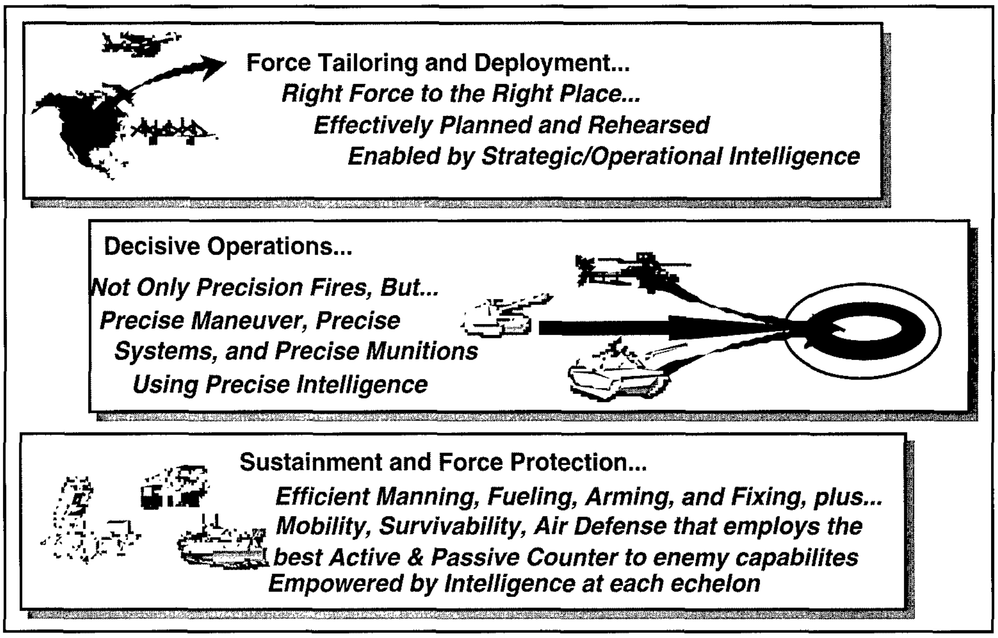
Precision in operations goes beyond precision strike; it includes every aspect of military operations from deployment through combat and

Figure II-11. Multi-Dimensional Battlespace



Must Account for Both Physical and Other Dimensions

Figure II-12. Precision in Operations



redeployment or transition to other operations. In force projection this means getting the right force, effectively trained and rehearsed, to the right place on time. In combat operations, precision means precise maneuver, positioning elements correctly in time and space, complemented by precision systems and precision munitions, and setting conditions which minimize the enemies' ability to rapidly respond and desynchronize our capabilities. Precision in force protection includes employing dynamic obstacles synchronized in time and space which create either protective or shaping effects; additionally air/missile defenses must be effectively employed to counter each enemy capability based on intelligence at each echelon. Precision in sustainment includes proactive arming, fueling, fixing, and manning empowered by common situational awareness of requirements and asset availability.

c. Non-Linear

Force XXI Operations are characterized by non-linearity, executing tasks across the entire battlespace rather than massing combat power at the Forward Line of Troops (FLOT). Nonlinear operations do not seek a rigid organization of the battlespace into close, deep, and rear operations. Instead, the battlespace is fluid, changing as METT-T changes through the duration of mission preparation and execution. Peacetime engagement, humanitarian assistance, and peacekeeping missions are generally executed non-linearly, conforming to the physical characteristics or infrastructure of the area of operations or based on mission requirements. Non-linearity requires soldiers and leaders to possess greater situational awareness, allowing risk to be accepted with space between units rather than more traditional contiguous operations. Non-linearity also increases the requirement on each divisional element for all-around security. (See Figure II-13.)

d. Distributed

Employing our emerging capabilities, operations and functions are executed throughout the depth, width, and height of our battlespace. These operations are distributed, that is, executed where and when required to achieve decisive effects vice concentrated at a possibly decisive point. Key to distributed operations is the empowerment of soldiers and leaders to use their initiative, willpower, and professional expertise to carry out critical tasks at all echelons. (See Figure II-14.)

Distribution enables Army elements to take advantage of internetted communications avoiding the tendency to use the chain of command as the chain of information. Dispersion empowers subordinates to operate independently within the commander's intent, leading to synergistic effects that exceed synchronization by a centralized headquarters. Distributed operations lead to agility, with greater flexibility to react to multiple changes in the situation. There are certain functions that are best executed centrally, primarily management of resources. Force

Figure II-13. Non-Linear Operations

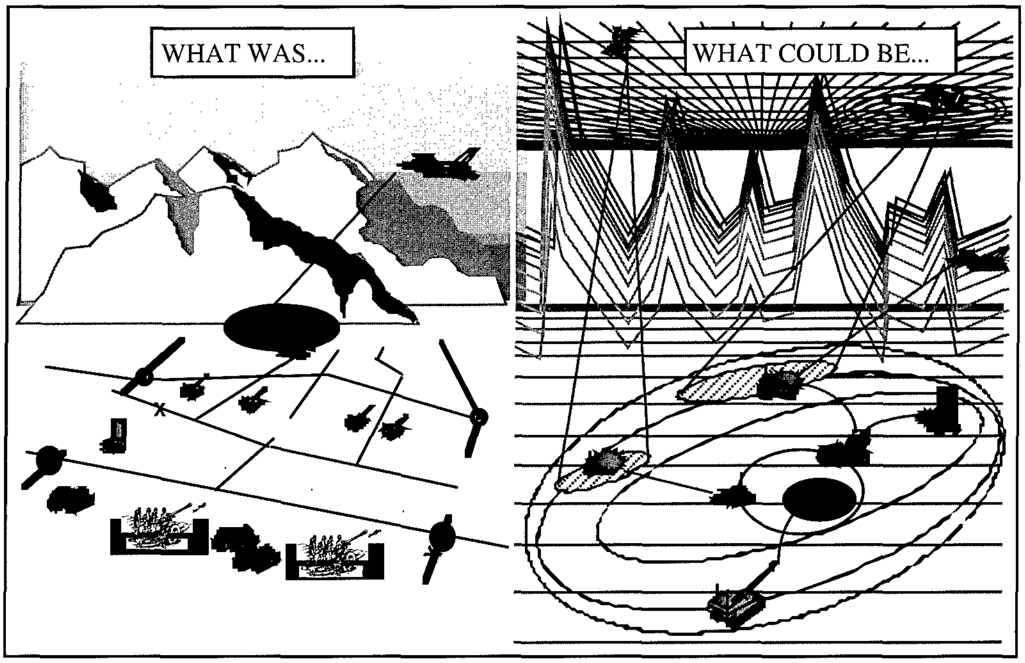


Figure II-14. Moving Towards Distributed Operations

Centralized	***Distributed***
Concentrate	**Disperse**
Sequential	**Simultaneous**
Hierarchical	**Internetted**
Delayed	**Real Time**
Linear	**Non-Linear**
Fixed Structure	**Fluid**
Static	**Agile**

Distributed Operations maximize the advantages gained from information and superior soldier/leaders

Central Intent/Concept...
Parallel Planning...
Decentralized Execution!

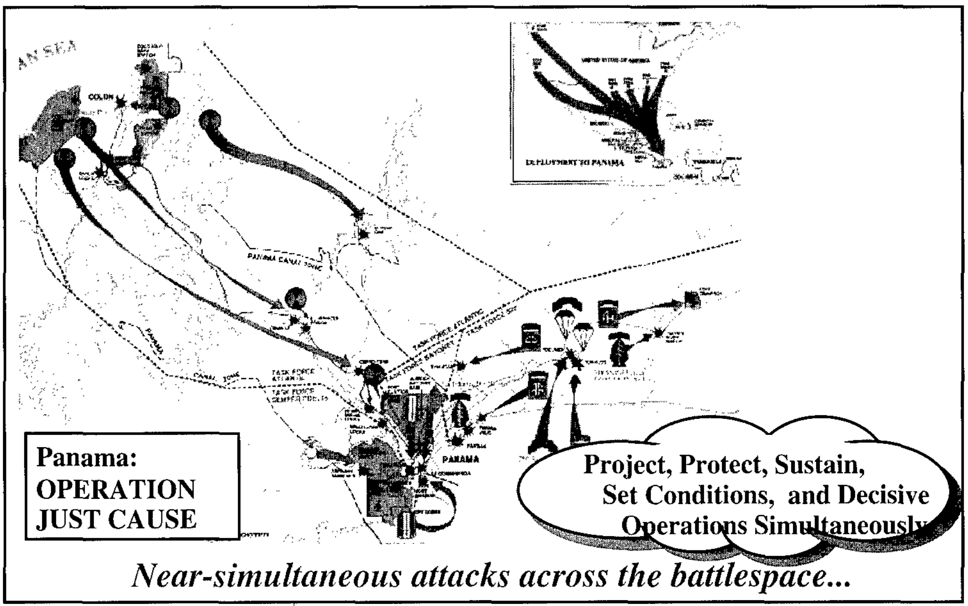
XXI Operations seek to execute each function using the best operational scheme. Through experimentation and operational experience, it appears the best approach is develop a central intent and concept, conduct parallel planning and coordination enabled by digitization, and execute distributed operations to achieve the objective.

e. Simultaneous

The concept of decentralized operations that are multidimensional, precise, distributed, and non-linear yields the capability to conduct simultaneous operations across the battlespace. Simultaneous operations seize the initiative and present the enemy leadership with multiple crises, but no effective response. Digitization creates the ability to plan, coordinate, and execute actions simultaneously. Each of these actions creates an effect, the sum of which is greater than if they were discrete and sequential. Rather than a single concentrated attack, we execute a series of attacks (lethal and non-lethal) as near-simultaneously as possible. (See Figure II-15.)

For distributed operations to have a decisive effect upon the adversary, they must be conducted at a tempo and sequence that he cannot

Figure II-15. Simultaneity

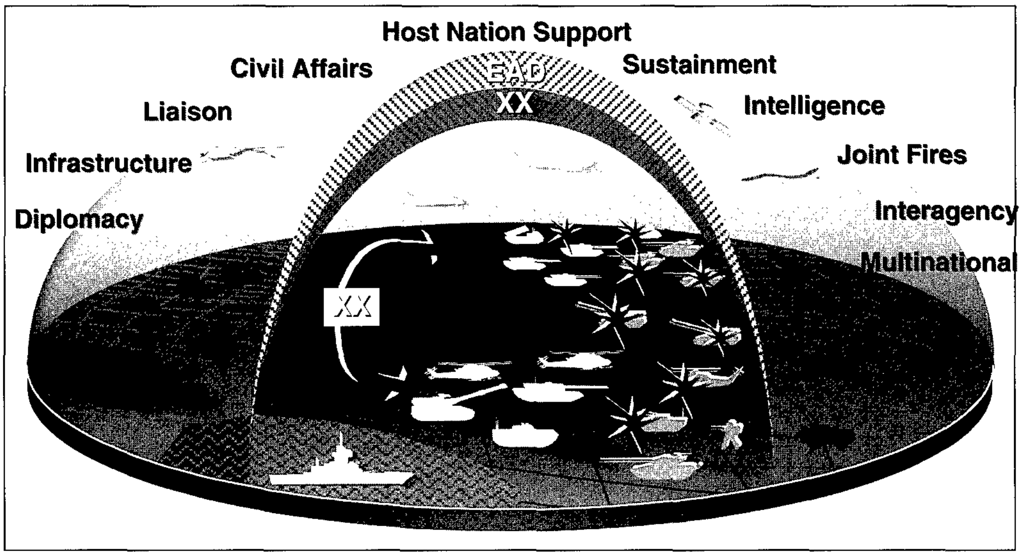


endure. The principle of simultaneity of action is paramount to the success of Decisive Operations. Commanders determine critical objectives and the sequence of actions to overwhelm the adversary's combat and support structures in a near-simultaneous manner to cause rapid defeat or collapse. Upon indication of collapse, highly mobile forces exploit by fires and maneuver to gain control and dominate the contested battlespace.

f. Integrated

Force XXI Operations are fully integrated with Joint, multinational, and non governmental partners. Recent experience has reminded us that Army operations have never been and will never be independent. From initial receipt of mission, through deployment, operations, and transition to follow-on operations Army elements function as an integral part of a Joint Task Force. That Joint Task Force is linked to Coalition partners and usually operates in conjunction with one or more non-governmental agencies such as the International Red Cross, United Nations, etc. Integrated operations enable the Army to leverage the full suite of capabilities the services bring to the battlespace. Army helicopters operating from Navy aircraft carriers during Operation Restore Democracy and TMD warnings from SPACECOM are two examples of fully integrated operations. (See Figure II-16.)

Figure II-16. Integrated Battlespace



2. Force XXI Patterns of Operation

a. Project the Force

Force XXI will be a power projection Army. No matter where future conflicts or military operations take place a portion of the force will have to deploy to the theater. But, projecting the force is far more than deployment. Power projection begins with receipt and analysis of the mission. Force XXI's modularity enables rapid and effective tailoring of the force based on METT-T. Concurrent with building the force is mission planning and rehearsal. Automated systems and simulations provide the capability to plan, coordinate, and wargame, leading to team building and training that results in effective execution immediately upon arrival in theater. (See Figure II-17.)

Army forces will be prepared to deploy from CONUS or from a forward station not in the AOR. First come early entry forces, either with their equipment or marrying up with prepositioned stocks. The prepositioning afloat of brigade sets of equipment provides operational agility and rapid reaction in crisis situations. Forced entry forces (Airborne, airmobile, SOF) may deploy straight into combat operations leveraging simultaneous, distributed operations to dictate the tempo and manner of the fight.

Deployment of the force directly into operations is paramount. Our Army can no longer afford the deploy, stage, move to combat paradigm. Enroute battle command will enable adjustment of plans and execution of combat operations during and immediately after deployment. Streamlined logistics, characterized by Total Asset Visibility and Split-Based operations, will support early operations upon arrival in theater.

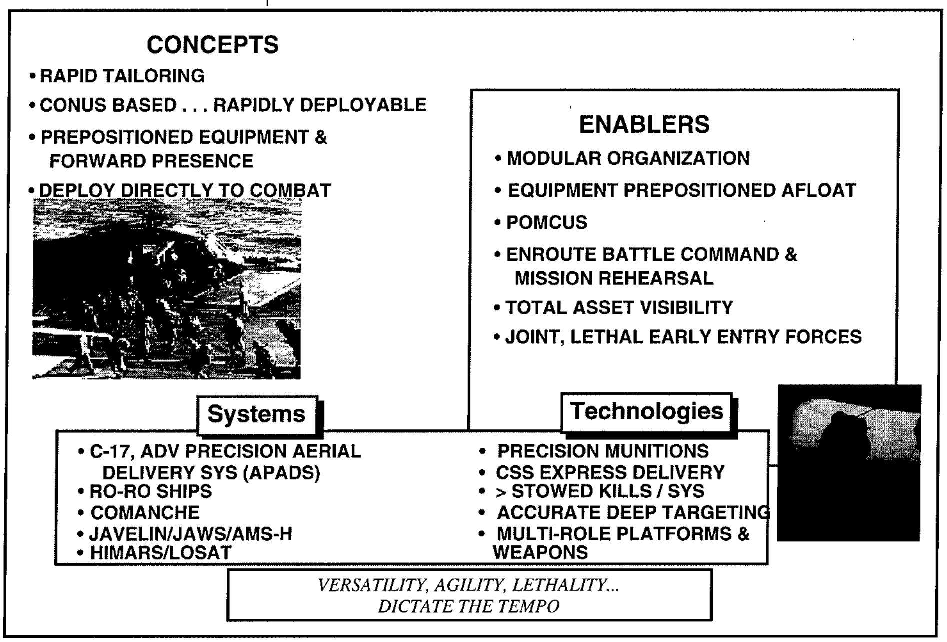
Projecting the force is absolutely a Joint, Integrated operation. Joint not only in how we deploy, but in how each service fights and supports while projecting the force. Additionally, even while projecting the force, Army elements are beginning to Gain Information Dominance, Shape the Battlespace, and even conduct Decisive Operations.

b. Protect the Force

The Force XXI approach to force protection will be a holistic one, incorporating organizational, materiel, and procedural solutions to the challenge of protecting soldiers and equipment. Protect the Force solutions have been developed through both experimentation and practical experience in contingency operations. Army digital capabilities enhance these solutions acr DTLOMS.

Common situational awareness enables early and accurate IPB. That IPB optimizes employment of security forces by signaling where a threat will appear that requires active security

Figure II-17. Project the Force



measures. Situational awareness also facilitates greater dispersion, increasing enemy targeting difficulties. Dispersion, elasticity, simultaneity enhance deception. Deception inhibits enemy prediction of friendly actions which not only promotes decisive operations, but also protects the force. Precision emplacement of dynamic obstacles, getting the right obstacle in the right place, in time will increase Army force lethality and survivability simultaneously. (See Figure II-18.)

From experimentation a scheme of protection has emerged. This approach builds first on the stealth approach—If you can't be found you can't be hit. Traditional means such as camouflage and smoke are integrated with counter-recon efforts such as using air defense elements to defeat UAV sensor platforms. If detected, Army elements attempt to prevent acquisition—don't give the enemy the chance to target you. Agility, mobility, and operations in reduced visibility prevent acquisition. If acquired, avert a hit through techniques such as missile avoidance drills. If hit, survive the hit through means such as enhanced ballistic protection or telemedicine.

A critical means of protecting the force is preemptive attack. The TMD AWE has demonstrated that improved sensors, shooters, and linkages will enable defeat of enemy attacks even before they occur. That AWE also confirmed that protecting the force is a multi-dimensional, Joint endeavor, requiring cooperation and interoperability. Taken together, Protect the Force efforts ensure sufficient combat power remains available for combat and other military operations while preserving the lives of our soldiers.

c. Gain Information Dominance

A great deal of theoretical work has been done with information over the past several years. What Force XXI experimentation provides us is practical experience in conduct of Information Operations (IO). Dominating Information Operations means creating a disparity between what we know about our battlespace and operations within it and what the enemy knows. If the disparity is great enough our soldiers and leaders at each echelon are making informed decisions while the enemy is guessing based on incomplete or erroneous information. Our leaders are able to influence the battle, while enemy leadership is isolated and powerless. (See Figure II-19.)

Even before a contingency arises, strategic IO are being conducted around the globe. Once the decision is made to commit military forces, that strategic information is enhanced by theater, joint, and coalition collection efforts. Early in the projection of force, information is used to tailor the force and plan campaigns and operations. Equally early in the campaign, the give and take of information warfare commences as

Figure II-18. Protect the Force

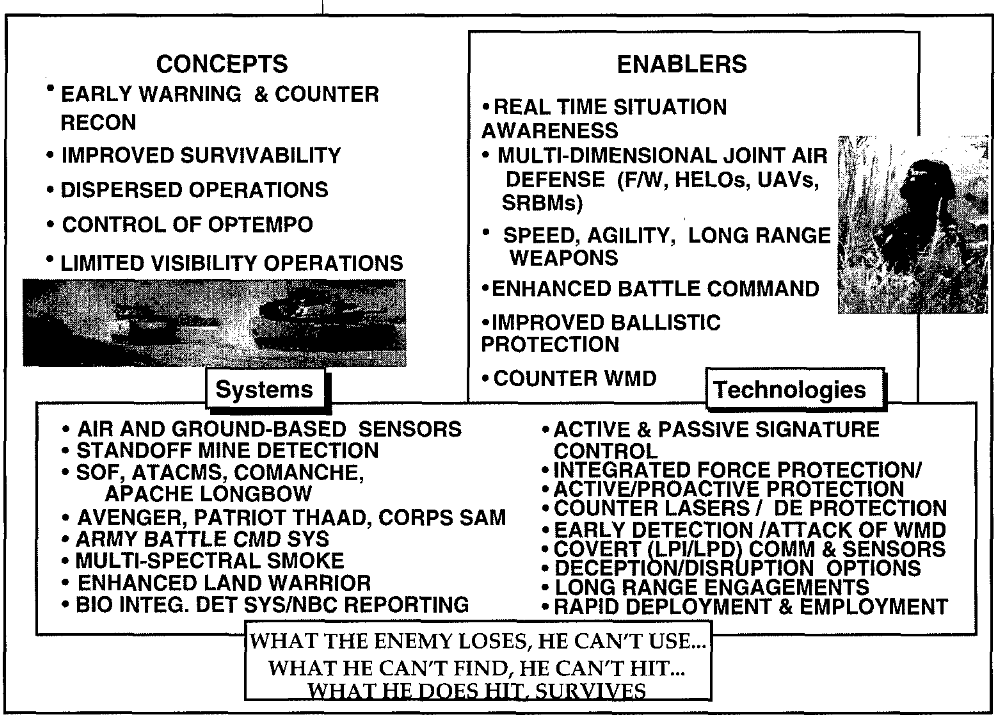
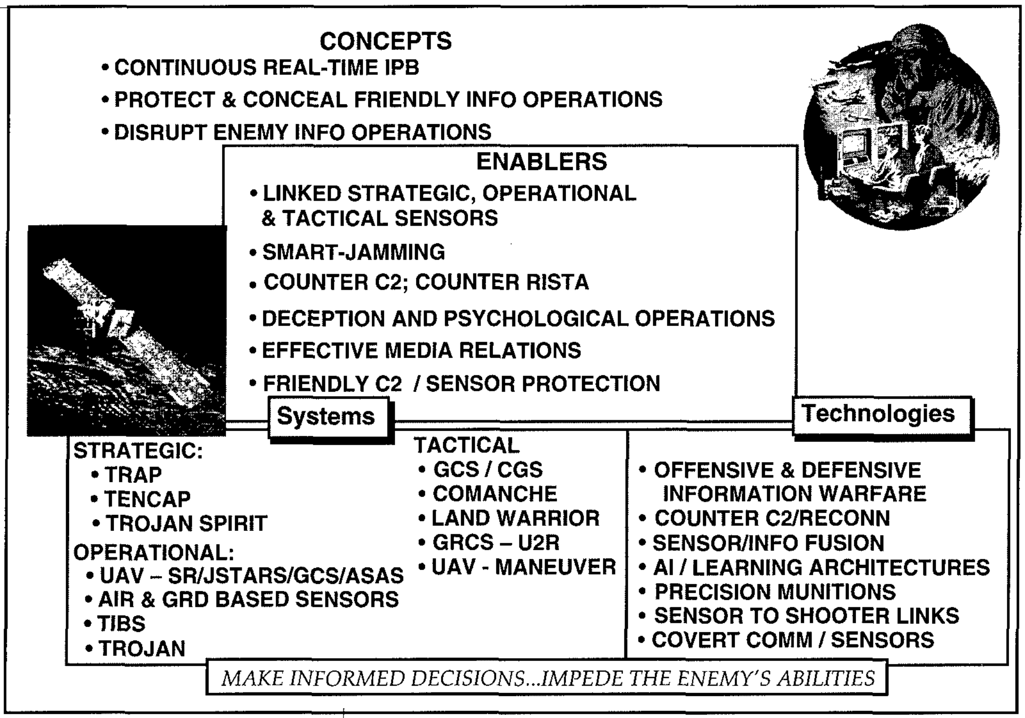


Figure II-19. Gain Information Dominance



opponents seek, through both offensive and defensive measures, information dominance at each echelon. The combative nature of IO means that information dominance is neither assured or continuous. This means that over time U.S. Army forces may have to fight under conditions of information parity or less. Even when possessing information dominance, enemy forces may have niche capabilities that overmatch some aspects of friendly operations. But IO is not only information warfare. It includes establishing and maintaining the means of using information (communications nets, digitized networks).

Army IO are conducted within the context of Joint IO, including PSYOPS and Deception campaigns, as well as media and global information operations. Successful IO results not only in eliminating enemy information capabilities, but also provides greater clarity to battle command through improved situational awareness. Most importantly, Gaining Information Dominance is key to Shaping Battlespace for Decisive Operations.

d. Shape the Battlespace

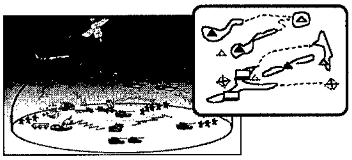
The purpose of shaping battlespace is to set the conditions for friendly success in decisive operations. Shaping battlespace is far more than the traditional preparatory fires or deep battle. Instead, we set conditions in terms not only of what we do to the enemy, but also of how we posture the friendly force and take advantage of the operational environment (terrain, weather, and infrastructure). The overall goal is to eliminate the enemy's capability to fight in a coherent manner before committing forces to decisive operations. (See Figure II-20.)

Shaping the battlespace begins with early, continuous, precise Intelligence Preparation of the Battlespace (IPB). This enhances Joint as well as Army fires, even during early entry operations. IPB supports identification of the enemy main effort and key enablers. Lethal and non-lethal fires strike to eliminate enemy critical capabilities while sensors locate and track the enemy main effort. That main effort is fixed in time and space not by traditional blocking positions, but rather through counter-mobility, friendly maneuver, command and control warfare, and fires. The battlespace is further shaped by dynamic obstacles employed precisely in time and space through enhanced situational awareness. Economy of force operations, including civil and public affairs, counter-intelligence, and military police allow decisive operations to mass effects against the enemy main effort.

As with information operations, friendly forces cannot count on automatically shaping the battlespace as desired. Instead, we seek to create windows of advantage by setting conditions for decisive operations, evaluating the results, then

Figure II-20. Shape the Battlespace

CONCEPTS
- EARLY, PRECISE, REAL-TIME IPB
- DOMINATE EXPANDED BATTLESPACE
- DESTROY KEY ENEMY CAPABILITIES EARLY
- SIMULTANEITY
- CONTROL OPTEMPO



ENABLERS
- LINKED STRATEGIC, OPERATIONAL & TACTICAL SENSORS
- SENSOR-SHOOTER LINKS / HUMNT
- DYNAMIC OBSTACLES
- INCREASED LETHALITY . . . EXTENDED RANGES, PRECISION MUNITIONS, MORE LETHAL MUNITIONS
- SIMULTANEOUS APPLICATION OF JOINT CAPABILITIES
- CIVILIAN-MILITARY OPERATIONS

Systems
- INTELLIGENT MINE FIELD/DEEP WAM
- ATACMS/ER MLRS/MSTAR
- APACHE – LONGBOW / COMANCHE
- C2/SENSOR ATTACK CAPABILITIES
- SOF/PSYOPS

Technologies
- INTEGRATED, FUSED SENSORS
- SMART, PRECISION MUNITIONS
- DECEPTION & DISRUPTION OPTIONS
- REMOTE WARFARE SENSORS/MUNITIONS
- REMOTE MISSILE LAUNCHERS
- COUNTER C2/SENSORS/LASERS

SET CONDITIONS FOR FRIENDLY SUCCESS...POSTURE THE ENEMY TO FAIL

setting conditions for another decisive action. These "windows of opportunity" must be planned, coordinated, and established in time and space for success. That success, either in offense or defense, is achieved through Decisive Operations.

e. Conduct Decisive Operations

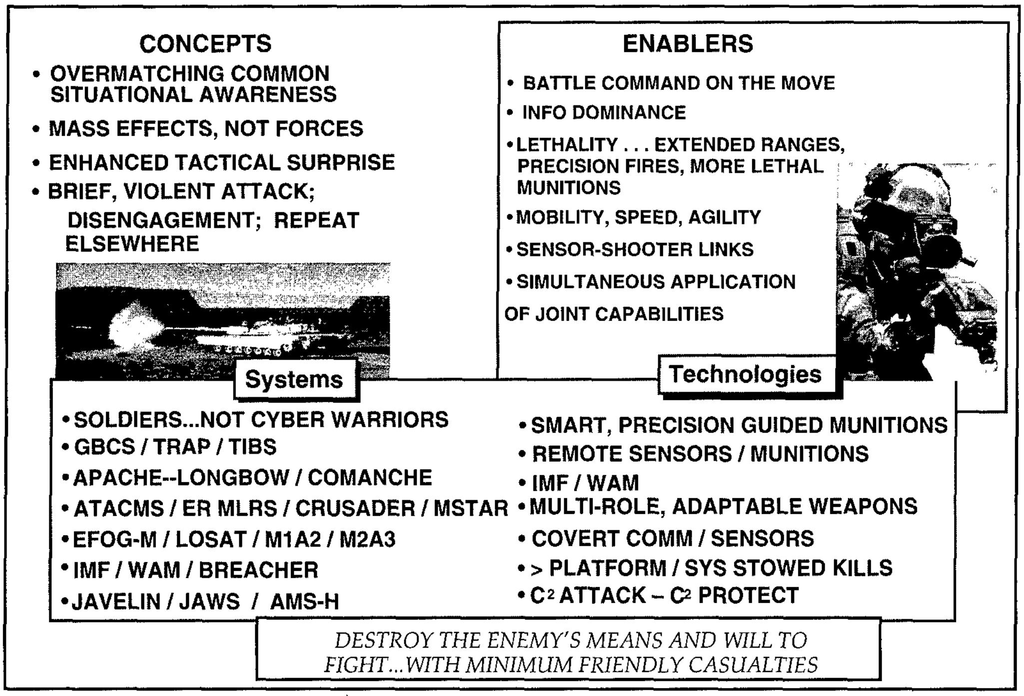
Decisive Operations are just that—the military operations that force the enemy to decide to give in to our will. In combat operations, decisiveness is measured in terms of victory in campaigns, battles, or engagements. In other military operations, it is measured in terms of accomplishing the military objectives (free elections in Haiti or the absence of war in Bosnia are examples). Within the pattern of operations, decisive operations are the means of achieving success. (See Figure II-21.)

Decisive Operations require the precise integration and application of combat power and combat multipliers throughout the enemy formation in depth—and in all dimensions to quickly defeat him. Concurrently striking the enemy at multiple critical points in a specific sequence, appearing to the enemy as a simultaneous action, will destroy his critical forces and functions—bringing rapid defeat of his force as a whole.

Decisive operations will be more Joint in nature, as the land force commander draws from a suite of capabilities the services bring to the battle. Due to the dynamic nature of crisis situations, land-based tactical forces must anticipate, plan, and prepare for decisive operations to provide the NCA or CINC an instantaneous tactical option if required. This requires setting conditions for decisive attack even while other options are being employed. The land force commander must integrate all aspects of decisive operations, ensuring coherency of intent and synergy in execution. The end result of decisive operations is the destruction of the enemy's means and will to fight.

Land combat in the early 21st Century will not appear markedly different than today—the tanks, howitzers, helicopters, and rifles used to apply combat power will be the same or slightly improved. What will be significantly different will be how we plan, coordinate, and execute the employment of those systems. Overmatching situational awareness, a product of digitization, will yield more precise, effective, and efficient maneuver and fires; as well as precision employment of dynamic obstacles and other combat multipliers. This will enable Army elements to mass effects without the risk of massing forces. Information dominance will enhance tactical surprise, so that we fight when and where we want, on our terms. The end result of decisive operations is the destruction of the enemy's means and will to fight.

Figure II-21. Decisive Operations

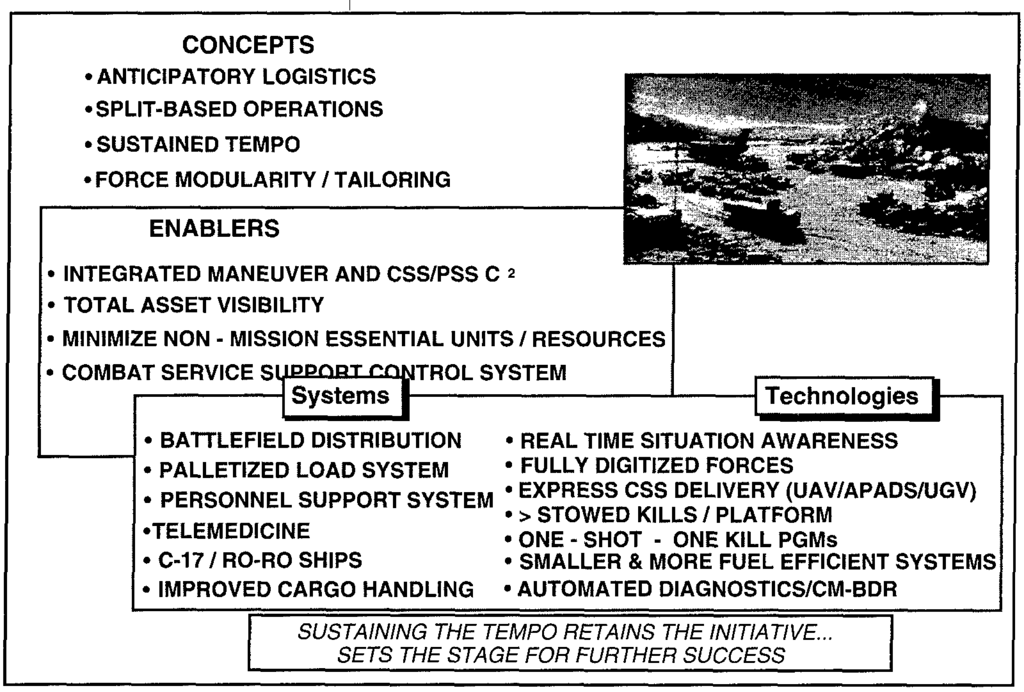


f. Sustain the Force

Sustainment remains an ongoing effort throughout the entire pattern of operations. Force XXI Operations seek not only to seize the initiative and dictate the tempo, but also to maintain that tempo over time. That capability will only be realized through improved logistics. Force XXI Sustainment is a combined arms effort, using solutions across DTLOMS, not just the responsibility of the logistician. (See Figure II-22.)

Key to Sustainment is anticipatory logistics, enabled by digitization. The concept of Total Asset Visibility (TAV), developed in AWEs and refined in operations in Somalia, Macedonia and Haiti, increases the efficiency and timeliness of logistics. Common situational awareness and TAV taken together enable logisticians to make informed decisions, allowing Army elements to execute proactive vice reactive logistics.

Figure II-22. Sustain Operations



Army power projection must be accomplished through split-based operations. Deploying only those logistical capabilities absolutely required to the theater increases the agility of the force. Integration of CSS automation systems within the Army Battle Command System (ABCS) is critical to execution of split-based operations. That integration facilitates the flow of logistical requirements and synchronization of support activities, also enhancing throughput and increasing the velocity of logistics support.

Flexibility and tailorability of the force is absolutely critical in contingency operations. Modular structure of CSS elements means logistical packages can rapidly be formed based on METT-T. Modularity also allows a smooth transition between combat and other military operations, where support requirements will change substantially.

Increasing the pace of logistical operations to match that of maneuver is required if we are to dominate tempo. The addition of battlefield distribution, palletized load system, and improved cargo handling technologies will significantly alter the speed at which we execute service support. Key also will be reinforcement of the existing infrastructure within the battlespace. Integration of materiel capabilities with operational and organizational innovations into an overall Sustainment Concept will enable full execution of Force XXI Operations.

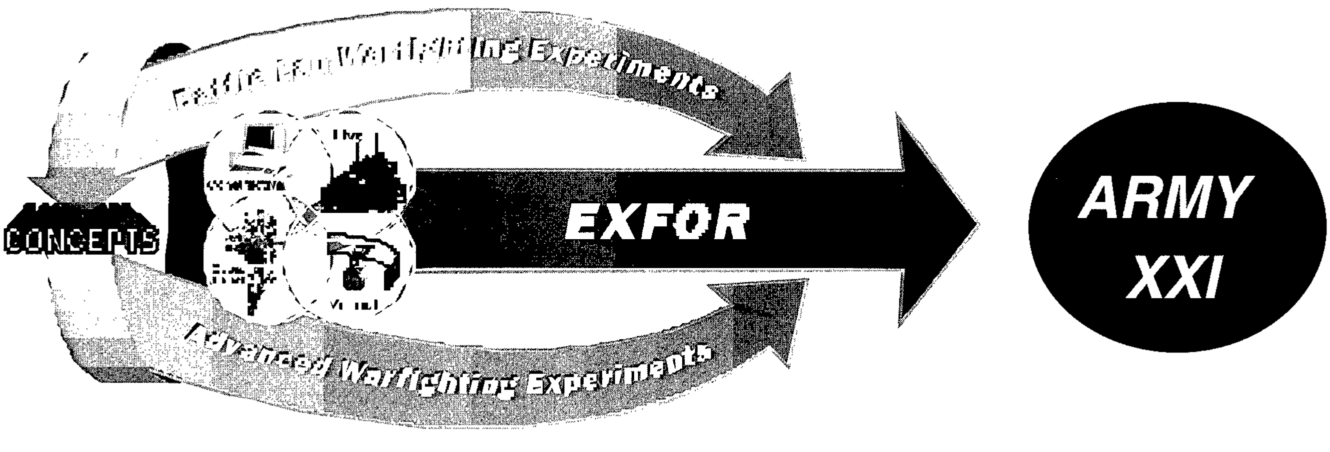
3. Current Status

During the last four years the Battle Lab process has been validated through a succession of Advanced Warfighting Experiments and a related series of "How to Fight" seminars and videos. The concept, through its ever-evolving process, has been continuously updated. The process output can be seen in Force XXI.

Warfighting experiments, large and small, are the keys to Force XXI Joint Venture success. Now the Joint Venture provides the focus for current and future warfighting experiments. (See Figure II-23.)

Six AWEs were approved for the Fall of 1994 through 1995. The first AWE was the Atlantic Resolve REFORGER exercise in November 1994. It provided insights about linking disparate constructive, virtual, and live simulations in a "synthetic theater of war" or STOW. The second AWE was the Theater Missile Defense experiment in April. It was a holistic exploration of ways to integrate national, joint, and Army capabilities into a cohesive tactical missile defense force that is able to counter potential adversaries during pre-attack, attack, and post-attack operational phases. The third AWE was the Mobile Strike Force (MSF) experiment in the Prairie Warrior exercise in May. The MSF explored future division-level organizational, materiel, and operational concepts that

Figure II-23. Battle Labs...Defining the Future



will influence the Force XXI division redesign efforts. The fourth AWE, Focused Dispatch, is a follow-on to the Desert Hammer VI AWE conducted in April 1994. It evaluated the processes and functions of digital connectivity among fire support, intelligence, combat service support, and battle command in a mounted battalion task force. The final 1995 AWE was the Warrior Focus experiment in November. It established the baseline for digitization of dismounted battalion task forces and continued the exploration of dismounted "own the night" issues. Finally, the Experimental Force (EXFOR), which is both an AWE and the means to conduct other warfighting experiments, was started in March 1995.

Insights from the most recent AWEs are as follows:

Theater Missile Defense

- Joint and Army Theater Missile Defense Doctrine needs revision
- Force Structure is inadequate
- C4I and Passive defense needs the most work
- Defense of forward maneuver forces against short range ballistic and cruise missiles is deficient

Prairie Warrior '95

- Successful Operational to Tactical level sensor hand-off
- Wide-area ambush appears practical
- Potential of ground maneuver not realized
- Aviation C2 does not support combat/combat support/combat service support mission
- Organization and functions of staffs

Focused Dispatch

- Potential for any sensor to any Fire Support node
- Current digital systems too slow for effective air defense early warning
- Comms pipe to pass info is insufficient
- Direction of individual Combat Service Support assets possible throughout the distribution process
- Execution done by voice
- Confidence in displayed info as "ground truth"

Warrior Focus

- Own-The-Night technology great success
- Connectivity issues remain but improving
- High level of discovery learning
- Technology for individual soldier a challenge

The AWEs completed to date and the "How to Fight" seminars have resulted in a better understanding of Force XXI.

4. Where Do We Go From Here?

The 4th Infantry Division (M) has been designated the Army's experimental force for the Brigade and Division experiments. In Phase I, the EXFOR began paving the way to ARMY XXI with their participation in Prairie Warrior '96. This exercise will be followed by the Brigade experiment at the National Training Center in Mar 97, and the Division Experiment in Nov 97.

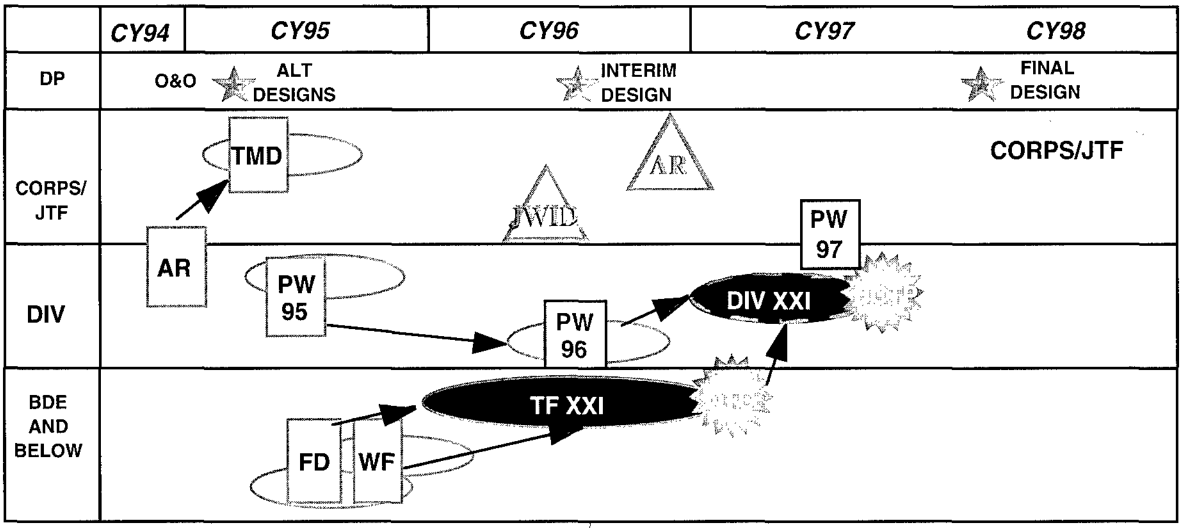
Phase II will define the Corps organizational changes and institutional Army changes needed for ARMY XXI. This phase will conclude in the 1998-99 time frame.

The third and final phase of the FORCE XXI campaign plan will be the FORCE XXI decisions being made the year 2000. (See Figure II-24.)

Task Force XXI is a step along the path, fed by NTC 94-07, and incorporating lessons learned from '95 AWEs. The operational concepts will be derived from TRADOC Pamphlet 525-5 and Force XXI division. Decisions will feed further experiments, especially the Division XXI AWE. The Brigade design will be refined and experimented with again as a live brigade in DIV XXI AWE from the EXFOR (Tank Bn, Mech Bn, En Bn, AVN TF).

The primary objective of the Division AWE is to validate the division design by using Synthetic Theater of War (STOW) capabilities, digitizing the Division headquarters, executing Division-Brigade digitized C3I interfaces/connectivity, and validating TTPs. This experiment will execute operations simultaneously—(1) BDE live, (1) BDE virtual,

Figure II-24. Advanced Warfighting Experiment Calendar



and (1) BDE constructive to gain insights on echelons above division (EAD)/Joint digitized operations. The experiment will culminate with a BCTP Warfighter in 1st QTR 98 (Nov 97).

The division AWE will examine:

- **How to organize**—combinations of combat, combat support, and combat service support units.
- **How to fight**—Tactics, techniques, and procedures.
- **How to command**—optimal process for each battlefield function and objective (expand battlespace, continuous operations, non-contiguous operations, and joint operations).

CHAPTER III

Technology Transition

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CHAPTER III

Technology Transition

Technology is changing the way literally everything in the Department of Defense is being done. And the faster we harness this technology in a way that the warfighter can use it, the more advantage we have over adversaries that we might meet out in the future.

Dr. Anita K. Jones
Director of Defense Research and Engineering

A. Introduction and Constraints

The ultimate goal of the Army's Science and Technology (S&T) program is to provide the soldier with a winning edge on the battlefield. The accelerating pace of technological change will continue to offer significant opportunities to enhance the survivability, lethality, deployability, and versatility of Army forces. High technology research and development is, and will remain, a central feature of the Army's modernization strategy.

The purpose of this chapter is to show the planned transition of promising technology developments into tomorrow's operational capabilities. This transition is accomplished by demonstrations which evolve into the systems and system upgrades incorporated in the *Army Modernization Plan* (AMP).

Because the ASTMP is designed to be a funding constrained document, inclusion of Systems/System Upgrades and demonstrations in Chapter III was based on their inclusion in the FY98–03 approved Army Program Objective Memorandum (POM), the FY97 Defense Appropriation, and the FY98–03 Budget Estimate Submit (BES).

The inclusion of Advanced Concepts is based on the existence of funded 6.3 technology demonstrations in the POM and in the RDA Plan, directed toward potential future systems. These Advanced Concepts represent options that are thought to be technologically achievable and useful on a future battlefield. There is, however, *no firm commitment* by either the Department of the Army or the user community to develop or produce these specific Advanced Concepts.

Systems and system upgrades contained in this chapter are also included in the approved *Army Modernization Plan.*

Most of the roadmaps contained in this chapter reflect only limited planned technology demonstration activity beyond the year 2000, due to the ever changing threat and the difficulty of projecting realistic far-term funding.

B. Technology Transition Strategy

1. Technology Transition

The basic strategy of the Army Science and Technology Program is to transition technology into operational systems to be prepared for future conflict. Because of significant changes in the world security environment over the past several years, the Army is currently focusing on building a smaller, power projection Army. This "new" Army will capitalize on America's technologies to improve critical areas of development such as protecting the individual soldier and improving battlefield mobility and information management.

Key to this strategy are the Technology Demonstrations (TDs), Advanced Technology Demonstrations (ATDs), and Advanced Concept Technology Demonstrations (ACTDs) that exploit technologies derived from applied research (6.2), which in turn build on new knowledge derived from basic research (6.1) programs. These TDs, ATDs, and ACTDs provide the basis for new systems, system upgrades, or advanced concepts which are further out in time. The critical challenge is to tie these programs together in an efficient and effective way.

Technology demonstrations are not new. What is new is the scope and depth of the technology demonstrations, the increased importance of their role in the acquisition process, and the increased emphasis on user involvement to permit an early and meaningful evaluation of overall military capability. The following sections provide an explanation of TDs, ATDs, and ACTDs, as well as Systems/System Upgrades and Advanced Concepts.

a. Technology Demonstrations

The primary focus of technology demonstrations is to demonstrate the feasibility and practicality of a technology for solving specific military deficiencies. They are incorporated during the various stages of the 6.2 and 6.3 development process and encourage technical competition. They are most often conducted in a non-operational (lab or field) environment. These demonstrations provide information that reduces uncertainties and subsequent engineering costs, while simultaneously providing valuable development and requirements data.

b. Advanced Technology Demonstrations (ATDs)—Current

Within each Army Mission Area, specific ATDs are being structured to meet established goals. Detailed roadmaps to guide their progress are being developed, as well as exit criteria to define their goals. ATDs are risk reducing, integrated, "proof of principle" demonstrations designed to assist near-term system developments in satisfying specific operational capability needs. The ATD approach has been promoted by the Defense Science Board and the Army Science Board as a means of accelerating the introduction of new technologies into operational systems. They are principally funded with advanced technology development (6.3) funds. ATDs facilitate the integration of proposed technologies into full system demonstration/validation (6.4) or engineering and manufacturing development (6.5) prototype systems. As such, they provide the link between the technology developer, program manager, program executive officer, and the Army user. The criteria for establishing an ATD are:

- Execution at the system or major subsystem level in an operational or simulated operational rather than a laboratory environment.
- Potential for new or enhanced military operational capability or cost effectiveness.
- Duration of three to five years.
- Transition plan in place for known and/or potential applications.
- Active participation by TRADOC Battle Lab and user proponents (see Chapter II).
- Participation by the developer (project manager).
- Use of simulation to assess doctrine/tactical payoffs.
- Exit criteria established with user interaction/concurrence.
- Consist ent with the Army Technical Architecture.

The Army currently has 23 ATDs which have been approved by the Army Science and Technology Working Group (ASTWG). These ATDs are identified in Table III-B-1, along with the primary Army Mission Area each supports. All ATDs are discussed in the applicable Chapter III section. More detailed information including exit criteria for each ATD can be found in Volume II, Annex B. Science and Technology Objectives (STOs) for each ATD are located in Volume II, Annex A.

c. Advanced Technology Demonstrations (ATDs)—Completed

Seven ATDs were successfully completed in FY96. Table III-B-2 provides details on the results of these ATDs, addressing the product, warfighting capability, and transition of the technology. Additionally, a brief description of these ATDs follows:

Advanced Airdrop for Land Combat ATD (93-96). This ATD demonstrated the Guided Parafoil Air Delivery System (GPADS), an autonomously guided, high altitude, offset airdrop system for precision delivery of military equipment, vehicles, and supplies. The GPADS provides the warfighter with a new capability—the ability to autonomously deliver payloads weighing up to 21 tons accurately (within 100 meters of the target) and from high altitudes (25,000 feet) and offset distances (12 miles). This capability greatly increases both the survivability of the delivery aircraft and the accuracy of the delivery, thus increasing time to

Table III-B-1. Current Advanced Technology Demonstration

ATDs	PRIMARY MISSION AREA/ CHAPTER III SECTION
FY93 Starts	
Battlefield Combat Identification	Intelligence and Electronic Warfare (III.F)
Intelligent Minefield	Engineer and Mine Warfare (III.M)
Rotorcraft Pilot's Associate	Aviation (III.D)
FY94 Starts	
Composite Armored Vehicle	Mounted Forces (III.G)
Enhanced Fiber Optic Guided Missile	Close Combat Light (III.H)
Hunter Sensor Suite	Close Combat Light (III.H)
Precision Guided Mortar Munition	Close Combat Light (III.H)
Total Distribution	Logistics (III.D)
FY95 Starts	
Digital Battlefield Communications	Command, Control, Communications, and Computers (III.E)
Hit Avoidance	Mounted Forces (III.G)
Guided MLRS	Fire Support (III.N)
Objective Individual Combat Weapon	Soldier Systems (III.I)
Target Acquisition	Mounted Forces (III.G)
FY96 Starts	
Direct Fire Lethality	Mounted Forces (III.G)
Integrated Biodetection	Nuclear, Biological, Chemical (III.K)
Vehicular Mounted Mine Detector	Engineer and Mine Warfare (III.M)
FY97 Starts	
Multispectral Countermeasures	Aviation (III.D)
Air/Land Enhanced Reconnaissance and Targeting	Aviation (III.D)
Battlespace Command and Control	Command, Control, Communications, and Computers (III.E)
FY98 Starts	
Future Scout and Cavalry System	Mounted Forces (III.G)
Mine Hunter Killer	Engineer and Mine Warfare (III.M)
Multi-Function Staring Sensor Suite	Mounted Forces (III.G)
Indirect Precision Fire	Fire Support (III.N)

Table III-B-2. Completed Advanced Technology Demonstrations

ATD	PRODUCT	WARFIGHTING CAPABILITY	TRANSITION
Advanced Airdrop for Land Combat	• Guided Parafoil Air Delivery System (GPADS) – Medium (11K lb payload) and Heavy (34K lb payload); autonomously guided airdrop systems each consisting of a large parafoil integrated with a GPS-based guidance, navigation, and control system	• GPADS provides the warfighter with the ability to deliver critical supplies and equipment accurately (100 meters from the target) from high altitudes (25,000 ft) and offset distances (12 miles), enhancing the capability of the military to respond to a broader spectrum of air delivery missions	• NASA will continue development of GPADS technology. GPADS is the proposed recovery system for the Experimental Crew Return Vehicle (X-CRV)
Advanced Image Intensification	• The next generation of night vision goggles for aviation and ground maneuver forces	• Enhanced operational effectiveness and safety • Increased field of view from 40 to 60 percent • Increased low light vision by >25 percent • Integrated display of flight symbology, Thermal Weapon Sight, and computer graphics • Improved capability to fly and fight at night	• Force XXI Land Warrior • Dismounted Soldier (Land Warrior) • Aviation system applications (SOF, cargo, utility, and current Scout vehicle) • Combat Service Support Battle Lab
Bistatic Radar for Weapons Location	• A 3-D bistatic radar system – survivable and affordable – able to detect and track small targets with range/accuracy consistent with current and future requirements • A multibeam pulse chasing receiver incorporating multiple redundant synchronization techniques • A modular transmitter with remote expendable electronically scanned antenna	• A survivable radar for use against anti-radiation missile and other indirect fire threats • Real-time targeting capability for force protection • Enhanced range and accuracy modes • Reduced false alarm/location rate	• PM Firefinder for Firefinder P3I • Technology is applicable to Theater Missile and other Air Defense missions
Combined Arms Command and Control	• A digital C2 information systems architecture for shared situation awareness, a common battlefield view and horizontal information exchange for Brigade and below • Early Battlefield Digitization concepts and definitions • A recognized and accepted Systems Engineering process • Enhanced modeling and simulation tools to support AWEs and Force XXI • A C3 Systems architecture for CAC2 and Force XXI • Recommendations for standardizing C3 protocols and message sets	• Provides real-time force synchronization for combined arms • Definition of operational requirements for situation awareness, target handover, information flow, and message sets on the battlefield • Seamless information flow	• All ATD results will transition to Battlespace C2 ATD • System Performance Model to: – RFPI ACTD – PEO C3S (Applique) – PEO C3S (NTDR) – Warrior Focus/Focused Dispatch, Force XXI • HW/SW evaluation and digital system architecture to PEO C3S, PM Applique, and Force XXI • Radio simulation models to be used in platform simulators, AWEs, and STRICOM

(Continued)

Table III-B-2. Completed Advanced Technology Demonstrations (Continued)

ATD	PRODUCT	WARFIGHTING CAPABILITY	TRANSITION
Crewman's Associate	• An advanced crew station with enhanced displays and controls, allowing the crew to effectively utilize the increased amount of battlefield data available and effectively interface with other vehicles through CAC2	• Significant reductions in vehicle silhouette and weight (2-man crew station) • Integration of increasingly complex advanced subsystems for effective use by the warfighter • Reduction in soldier cognitive and psychomotor overload • Reduced time to acquire, engage, and kill a threat at long distances • Improved operations on the move and situational awareness • Decreased task execution timelines • Improved night operations and CONOPs	• Future Scout and Cavalry System ATD • PEO Armored Systems Modernization
Off-Route Smart Mine Clearance	• Technologies and concepts to neutralize advanced off-route smart mine systems – acoustic, seismic, and IR signature projection techniques for mine neutralization – signature management technologies to evade and survive the launch of a smart mine sublet or warhead • Clearaway system for obstacle breaching and main supply route clearing operations	• Defeats off-route smart mines – projects multispectral target signatures to initiate – misdirects mine munitions towards false acoustic/IR image – evades smart mine munitions through signature management technologies – utilized tele-operation to protect operator • Enhances overall mobility and survivability for heavy and light forces	• Joint Countermine ACTD • Lead Fighter Countermine BLE • PEO Armored Systems Modernization
Remote Sentry	• A compact, lightweight, integrated multisensor system capable of being implanted in forward areas and behind enemy lines to provide day/night, all weather, unmanned surveillance, and targeting information	• Extends Scout range and area of surveillance – capable of detecting human targets at >1100m and vehicle targets at >2200m – transmits imagery over combat net radio at a rate >1 frame/10 seconds • Increased forward Scout/observer survivability through battlefield awareness • Remotely controlled, interoperable sentries reduce field of regard "blind spots"	• RFPI ACTD • PEO IEW (PM NVEO)

operational readiness on the drop zone and the likelihood of mission success. The new technologies leveraged included ultra-large ram-air canopy designs, staged-reefing, and opening techniques; automated guidance and control on non-powered gliding accelerators; and automated soft landings.

Advanced Image Intensification (AI2) ATD (93-96). This ATD demonstrated the next generation of night vision goggles, which enhance operational effectiveness/safety and reduce pilot workload. The AI2 ATD exploited technology advanced in display and intensifier technologies, image intensification, optics, and human factors research. The results of this ATD were to provide significantly increased visual acuity and field of view, integrated symbology, and improved user interface.

Bistatic Radar for Weapons Location ATD (91-96). This ATD employed bistatic radar (transmitter and receiver are physically separated) techniques to detect and track mortars, artillery, and rockets for the purpose of weapons location and classification (for counterfire) and fire registration (for battle damage assessment). Bistatic radar provides significant advantages over conventional monostatic radars, as indicated by the following: the covert passive receiver is difficult to locate and/or jam, is immune to Anti-Radiation Missile threat, and provides significantly enhanced crew survivability; its superior size and weight distribution provides improved mobility; high performance with respect to target throughput, electronic counter-countermeasures, multiple mode, and multiple mission operation is more affordable; there are more deployment options; and surveillance volume can be better tailored to the non-linear battlefield.

Combined Arms Command and Control ATD (CAC2) (93-96). The CAC2 ATD developed and demonstrated C2 functionality and shared situational awareness for brigade and below, including Armor, Aviation, Mounted Forces, and Fire Support. The ATD used a series of simulations to establish operational concepts. Initially, the focus was on the capability of the Bradley Fighting Vehicles, tanks, and attack rotorcraft to share a common battlefield picture. The ATD then expanded upon Combat Vehicle C2/Intervehicular Information System technology bringing in C2 contributions and needs from other combined arms elements. Simulation, modeling, and rapid prototyping of both the C2 functions and communications requirements was then integrated into Battlefield Distributed Simulation -Developmental (BDS-D) for user evaluation and evolution. Subsequent simulations linked fire support target reporting and handover, followed by hot bench testing of the concepts. The ATD concluded in FY96 with a field demonstration and a combined demonstration with the Battlefield Combat Identification ATD.

Crewman's Associate ATD (93-96). The Crewman's Associate ATD was a coordinated program involving several AMC MSCs, laboratories, and PM Abrams which demonstrated, through modeling and soldier-in-the-loop virtual simulation, advanced crew station concepts. The Crewman's Associate provided the embedded weapon system with a gateway to the digital battlefield by developing crew stations with user-friendly interfaces, movement-friendly input devices and automation. Technologies included helmet-mounted displays, programmable display push-buttons, three-dimensional audio, voice-activated controls, and expert systems. The Crewman's Associate crew stations increase the warfighter's situational awareness and increase the ability to operate and fight on the move. Crew stations also enable soldiers to quickly understand and easily react to the increased volume of data available from the advanced sensors and digital C2 system of Force XXI.

Off-Route Smart Mine Clearance (ORSMC) (94-96). This ATD demonstrated countermeasure techniques to neutralize off-route smart mines and focused on defeating smart mines, such as side attack. Advances in sensor and digital signal processing technologies have resulted in the development of a family of mines capable of identifying and attacking targets from ranges of several hundred meters. ORSMC provides the capability to neutralize this threat by using a remotely controlled vehicle to emulate the acoustic and seismic signatures of combat vehicles and spoof the mines into a premature launch. A low observable suite for vehicle protection against mines was also developed as part of the ATD. ORSMC enhances the survivability of combat and logistical vehicles in situations ranging from breaching operations to logistical resupply of heavy and light forces.

Remote Sentry ATD (93-96). This ATD demonstrated a compact, lightweight, affordable, integrated multisensor system capable of being implanted behind enemy lines to provide day/night, adverse weather, unmanned surveillance, and targeting information. Data is transmitted to friendly weapons platforms using smart data compression techniques. The system provides integrated, low cost imaging, which includes an uncooled thermal imager and TV as well as acoustic and other target cueing and position/location sensors.

d. Advanced Concept Technology Demonstrations (ACTDs)

The ACTD is an integrating effort to assemble and demonstrate a significant, new military capability, based upon maturing advanced technology(s), in a real-time operation at a scale adequate to clearly establish operational utility and system integrity. ACTDs are jointly sponsored and implemented by the operational user and materiel development communities, with approval and oversight guidance from the Deputy Under Secretary of Defense for Advanced Technology (DUSD/AT).

The ACTD concept is a cornerstone in a procurement strategy that relies on prototyping and demonstration programs to maintain the U.S. military technological edge in the face of declining procurement budgets. ACTDs are a more mature phase of the ATDs. They are two- to four-year efforts in which new weapons and technologies are developed, prototyped, and then tested by the soldiers in the field for up to two years before being procured. This 2-year residual capability is a unique attribute of an ACTD.

ACTDs are not new programs, but tend to be a combination of previously identified ATDs, TDs, or concepts already begun. They include high level management and oversight to transform disparate technology development efforts conducted by the various military services into prototype systems that can be tested and eventually fielded. The ACTD becomes the last step in determining whether the military needs and can afford the new technology.

2. Manpower and Personnel Integration (MANPRINT) Program

MANPRINT is a comprehensive management and technical program to improve total system (soldier, equipment, and unit) performance by focusing on soldier performance and reliability. This is achieved by the continuous integration of manpower, personnel, training, human engineering, system safety, health hazards, and soldier survivability considerations throughout the materiel life cycle.

Throughout the design and development phases, MANPRINT ensures that an emphasis on soldier considerations is maintained as a high priority in system design; and that system operation, deployment/employment, and maintenance requirements are matched with soldier capabilities, training, and availability. The value added of MANPRINT has been demonstrated in programs such as Comanche and Longbow Apache, where application of MANPRINT has led to significant cost avoidance and enhanced mission effectiveness. With MANPRINT, Army systems will become increasingly user-centered, reliable, and maintainable, leading to significant reductions in life-cycle costs and increased mission effectiveness.

3. Army Strategy for Systems, System Upgrades, and Advanced Concepts

a. Systems and System Upgrades

The development of the next set of systems requires prior demonstration of the feasibility of employing new technologies. New systems are those next in line after the ones currently fielded or in production. For these systems, most technical barriers to the new capability have been overcome. Generally, these systems can enter engineering and manufacturing development relatively quickly as a result of the successful demonstration of enabling technologies. Based on current funding guidance, the number of new systems is in a sharp decline.

Systems included in this chapter must have a funded 6.4 or 6.5 development program and/or production dollars in the POM/Army RDA Plan.

In the absence of new systems, the Army is pursuing incremental improvements to existing systems to maintain its technological edge and capabilities. For the purposes of this plan, these improvements have been designated as "System Upgrades." System upgrades are brought about through technology insertion programs, service life extension programs, preplanned product improvement programs, and block improvement programs. System upgrades included here must have a 6.4/6.5 funding wedge in the POM/Army RDA Plan. These upgrades are based primarily on the success of funded 6.3 ATDs/TDs. The 6.3 ATDs/TDs either are the basis for the system upgrade or have a high probability of forming the basis for the system upgrade. Descriptions of systems and system upgrades may be found in the book *Weapon Systems, United States Army 1997.*

b. Advanced Concepts

Advanced Concepts are systems concepts further out in time. For these, significant technical barriers remain, and questions of military worth, including trade-offs within emerging doctrine and force structure limits, are less clear. Advanced concepts help provide the focus for the earlier stages of technology development (6.1 and 6.2 programs) and outyear projected 6.3 demonstrations. In many cases they are conceptual in nature, and actual system definitions may change significantly by the time technologies and demonstrations are more fully understood. Advanced concepts represent an option that is thought to be technologically achievable and useful on a future battlefield, but without a prior commitment by either the Department of the Army or the user community for development or production. Inclusion of advanced concepts in the ASTMP is based on planned/funded 6.3 ATDs/TDs.

4. Force Modernization Planning

The purpose of an *Army Modernization Plan* (AMP) is to formally state the Army's plan for force development and modernization and to clearly articulate specific goals. The AMP is the key planning document in providing long term continuity within functional areas, while assisting in program prioritization and integration of the total Army force. The AMP is constrained to available structure and programmed resources. It provides the structure and guidance necessary to integrate functional mission area solutions in a constrained resource environment. It is responsive to changing external factors such as emerging capabilities, funding levels, force structure, technology breakthroughs or delays, and the National Military Strategy. The current functional area annexes to the AMP are listed in section C.1.

5. Low Intensity Conflict/ Operations Other Than War

Due to the changing world situation, Low Intensity Conflict (LIC), and Operations Other Than War (OOTW) (i.e., Humanitarian Assistance, Peacekeeping Operations, and Peace Enforcement) are becoming increasingly important areas that must be addressed by the development community. This is reflected in the Combat Maneuver Annex (Close Combat Light) to the AMP. New technology is being used to develop systems which support the LIC/ OOTW mission. This usually equates in operational terms to equipment being lighter, smaller, more mobile, and less detectable. In each section of this chapter, where appropriate, ties to the Close Combat Light mission area are noted. Additional material is presented in Chapter III in a separate *Close Combat Light* section (III-H).

C. Chapter Organization

1. Contents of Chapter III

This chapter presents the transition of technology into Systems/System Upgrades and Advanced Concepts (S/SU/ACs) in 14 sections corresponding to the Annexes of the *FY97 Army Modernization Plan (AMP)*. Note that, because the AMP has recently been restructured, there is not a one-to-one correlation between the Chapter III ASTMP sections and the AMP Annexes. The ASTMP sections are as follows:

- Aviation
- Command, Control, Communications, and Computers
- Intelligence and Electronic Warfare
- Mounted Forces
- Close Combat Light
- Soldier
- Combat Health Support
- Nuclear, Biological, and Chemical
- Air Defense
- Engineer and Mine Warfare
- Fire Support
- Logistics
- Training
- Space

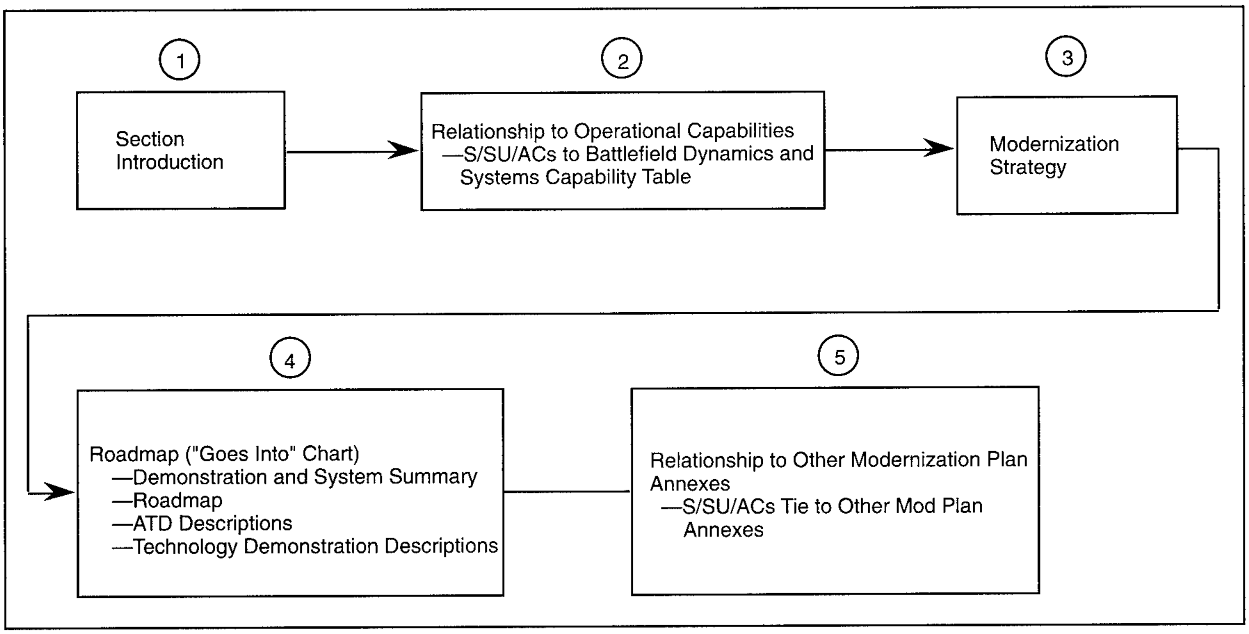
Although AMP Annexes currently exist for Force Structure, Information Mission Area, Missile Defense, and Tactical Wheeled Vehicles, there are no Army S&T-funded technology demonstrations planned. Therefore, there is no corresponding section for these Annexes included in Chapter III.

Each section includes a crosswalk, by system, showing the support to the applicable Modernization Plan Annexes. Additionally, each addresses the questions of "Why?" and "How?" The "Why?" part consists mainly of the discussion of operational capabilities. The "How?" part is addressed in the demonstration descriptions and the roadmap chart. Each section is built around the framework displayed in Figure III-C-1 and contains the following information:

Introduction—A quick synopsis which presents the theme and S&T efforts to be discussed in the section.

Relationship to Operational Capabilities—This section includes a table which ties S/SU/ACs to the applicable Training and Doctrine Command (TRADOC) Battlefield Dynamics and presents the specific new system capabilities required for each area. The function categories relate to the TRADOC Battlefield Dynamics. Capabilities were derived from TRADOC-defined

Figure III-C-1. Framework for Technology Transition Sections



Operational Capability Requirements (OCR)/ Future Operational Capabilities (FOC) (see Volume II, Annex C), AMP Annexes, system descriptions, and other related documents.

Modernization Strategy—A brief synopsis of the applicable modernization strategy is provided.

Roadmap—The roadmap is a graphical milestone representation of all the technology transition demonstrations which are covered in the section. It shows approximate time frames and associated systems for each demonstration. It also captures the evolution to advanced concepts. A summary table presents the systems and demonstrations found in each roadmap.

The roadmap is the heart of each section. The left hand side of the roadmap lists systems and system upgrades; the demonstrations and tie-ins are shown in the body of the map, and the evolution to advanced concepts is on the right side. (See the *C4 Modernization* roadmap, Figure III-E-1, for example.)

Following this, a description of technology demonstrations is provided. This includes a discussion of the technologies being demonstrated in terms of the capability to be provided. Some demonstrations have applications to more than one Modernization Plan Annex. In these cases, the demonstration is described in the primary section and referenced in the other applicable section. Each demonstration description identifies the S/SU/ACs being supported.

Relationship to Other Modernization Plan Annexes—This section presents a matrix displaying systems, system upgrades, or advanced concepts which are supported in, or contribute to, other *Army Modernization Plan* Annexes.

2. Relationship to Other Chapters

Chapter III represents the implementation of the Army's S&T planning process necessary to support the warfighting concepts discussed in Chapter II. It addresses the application of technologies, including emerging technologies, which are discussed in more detail in Chapter IV. Volume II, Annex A, provides the Science and Technology Objectives (STOs) relative to the ATDs and significant technology demonstrations. Descriptive information on the Advanced Technology Demonstrations may be found in Annex B, Volume II. In summary, Chapter III describes how the Army's S&T program comes together to transfer technology into systems that provide Army operational capabilities.

D. Aviation

Comanche is the centerpiece of the digital battle-field.

Brigadier General Orlin L. Mullen (Ret.)

1. Introduction

In support of the Army's five strategic modernization objectives, Army aviation showcases the development of the RAH-66 Comanche and AH-64 Apache Longbow helicopters. The armed reconnaissance Comanche will be the "centerpiece of the digital battlefield" and the Apache Longbow will provide "all weather" attack capability. Battlefield commanders will quickly realize the advantages gained through the instantaneous transfer of digital reconnaissance data to the airborne shooters and their three-dimensional maneuverability/agility to control the ever changing battlefield tempo. As the threat proliferates and increases the probability of regional and third world conflicts, the need for expanded aviation capabilities for deployability, lethality, versatility, and expansibility will continue to be ever critical.

Consistent with the *Army Modernization Plan* (AMP), the Science and Technology (S&T) program focuses on those projects which will be vital to Army Aviation's fulfillment of its future military role. The Army Aviation S&T Program will make major contributions to the Army's Battle Lab warfighting capabilities, Force XXI, the nation's rotorcraft industry, and NASA's rotorcraft programs. It is postured to support the potential for a Joint Transport Rotorcraft (JTR) which could meet military and commercial needs.

2. Relationship to Operational Capabilities

To meet the varied challenges of the 21st century, Army Aviation envisions the family of Systems/Systems Upgrades and Advanced Concepts (S/SU/ACs) listed in Table III-D-1. This table presents the correlation between the S/SU/ACs and relevant TRADOC Battlefield Dynamics. This large, diverse group of dynamics illustrates aviation's ability to support a wide range of combat operations. Army Aviation is an integral part of all Battlefield Dynamics. Table III-D-1 also shows the projected S/SU/ACs capabilities for the aviation functional missions.

Army Aviation will continue to be versatile and deployable. It will combine speed, mobility, and fire power in the attack/reconnaissance and assault forces, while moving and sustaining combat power at decisive points on the battlefield in its cargo/utility helicopters. With the evolution of Combined Arms Operations, Army Aviation will be even more important in the faster paced battles of the future.

3. Modernization Strategy

The Aviation Annex to the AMP provides a blueprint for equipping our aviation forces well into the next century with a modern, cost-effective, warfighting fleet able to meet the challenges of low-, mid-, and high-intensity conflicts. The AMP calls for the following major improvements:

- Upgrade existing systems: AH-64 Apache Longbow modernization, UH-60 Blackhawk, and Improved Cargo Helicopter (ICH).
- Conduct development: RAH-66 Comanche (including Longbow).
- Conduct development, upgrade existing systems, and sustain the numerous core programs.
- Support advanced concepts: Enhanced AH-64 Apache, Joint Transport Rotorcraft (JTR), and Bird Dog.

Current and future threats to Army aircraft are many and varied. The range of new and emerging technologies available to our adversaries further increases the threat. Many such technologies are intended to improve the effectiveness of air defense systems against low-flying helicopters, while other technologies strive to strengthen the protection of ground systems from attack by air. Undoubtedly, these technologies will become available on the international arms market, resulting in an even more robust capability for our potential adversaries. Our own warfighting concept and modernization requirements are both predicated on the need to counter known and emerging threats.

Table III-D-1. Aviation System Capabilities

S/SU/AC FUNCTION	BATTLEFIELD DYNAMICS: Early Entry	Depth and Simultaneous Attack	Mounted Battlespace	Dismounted Battlespace	Battle Command	Combat Service Support	SYSTEM/SYSTEM UPGRADE CAPABILITIES	ADVANCED CONCEPT CAPABILITIES
SCOUT/ATTACK							• Day/night and adverse weather • Integrated cockpit for reduced crew workload • Aided target recognition – Second Gen FLIR – EO/MMW radar – Expert system/processor • Antiarmor capability – Laser/RF Hellfire • Air-to-air capability – Advanced fire control – Stinger missiles – High rate of fire cannon • Area target capability – Hydra 70 rockets • Low-cost precision-kill 2.75" guided rockets (ATG/GTG) • Survivability – Signature reduction • Advanced flight controls – Fly by wire/light • Secure NOE Comm data transfer • Self deployable • Crashworthiness • Cockpit air bags	• Advanced propulsion • Advanced maneuverability/ agility • Integrated flight/fire control • All weather NOE pilotage • Computer-aided low altitude flight • Advanced weapons • Automatic target acquisition • Mission planning and rehearsal • Advanced man-machine integration – Situational awareness – AI/cognitive decision aiding • Precision navigation • B2C2 operational doctrine status • Secure comm-jam resistant • Multimodal command under-standing • NBC sensors and overpressure • NBC/DE/ballistic protection • Survivability/vulnerability • Susceptibility – signature control • Diagnostics/prognostics/ embedded training • Fault tolerant/AI processing • Ground maintenance associate • Self deployable • Crashworthiness • Two-level/paperless maintenance
System								
RAH-66 Comanche	●	●	●	●	●			
System Upgrade								
AH-64 Apache Longbow	●	●	●	●	○			
UH-60 Blackhawk	●	●	●	●	○			
Advanced Concepts								
Enhanced AH-64 Apache	●	●	●	●	○			
Bird Dog	●	●	○	○				
CARGO/UTILITY								
Advanced Concepts								
Improved Cargo Helicopter	●	●	●	●		●		• Range – Advanced propulsion/airfoils – Self deployable • Lift (advanced transmission) – Maximize load carrying – Minimum noise/vibration • Cargo handling – Increased payload, internal/ external – All weather/day/night, reduced time • NOE sling load operations – Precision nav/hover – Active load stabilization • Man-machine integration – Interactive displays/AI • Diagnostics/prognostics/ embedded training • Reduced signatures • Forward arming and refueling • Ground maintenance associate
Joint Transport Rotorcraft	●	●	●	●		●		

● Provides Significant Capability ○ Provides Some Capability

Desert Shield/Storm not only demonstrated Army Aviation's current ability to support Combined Arms Operations, but also validated the logic of the Army Aviation Modernization Strategy. These successes, plus future threats, justify our investments in the development of the RAH-66 Comanche as a responsive and timely evolution of aviation capabilities. The Army Aviation S&T program of the 1980s paved the way for these new systems, and the program for the 1990s is capitalizing on its successes. Fulfillment of our aviation modernization requirements will result in the achievement of strategic agility and power projection necessary to deploy, fight, and sustain forces—to win decisively with minimal casualties.

4. Roadmap for Army Aviation

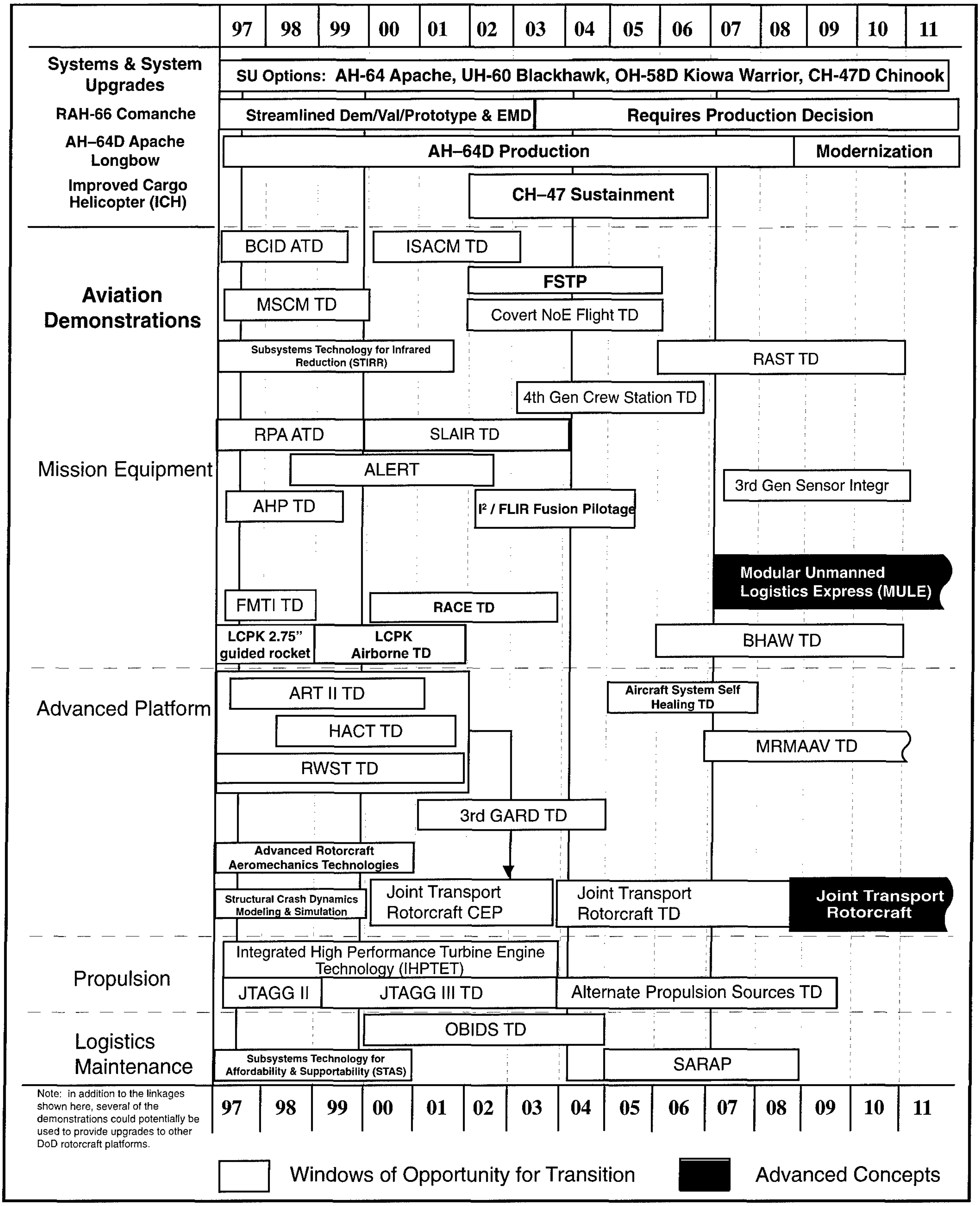
Table III-D-2 presents a summary S/SU/ACs and demonstrations in the Army Aviation S&T program that support the AMP. The roadmap for Aviation (Figure III-D-1) portrays the Army's use of Technology Demonstrations (TDs) and Advanced Technology Demonstrations (ATDs) to support the development of its future aviation systems, and dual use technology for the nation's rotorcraft industry. The aviation S/SU/ACs are shown at the top of the figure. The lower half of the figure shows the substantial block of aviation technology demonstrations that support the

Table III-D-2. Aviation Demonstration and System Summary

ATDs	TECHNOLOGY DEMONSTRATIONS
• Rotorcraft Pilot's Associate (RPA) • Battlefield Combat ID (BCID) (see *IEW*) • Air/Land Reconnaissance and Targeting (ALERT) • Multispectral Countermeasures (MSCM) (See Volume II, Annex B, for additional information.)	***Mission Equipment*** • Advanced Helicopter Pilotage (AHP) • I2/FLIR Fusion Pilotage • Integrated Situational Awareness and Countermeasures (ISACM) • Future Missile Technology Integration (FMTI) • Survivability/Lethality Advanced Integration in Rotorcraft (SLAIR) • Low Cost Precision Kill (LCPK) ATG/GTG 2.75" Guided Rocket • Low Cost Precision Kill - Airborne • Advanced Weapons Integration Program (AWIP) • Rotorcraft Air Combat Enhancement (RACE) • Full Spectrum Threat Protection • Covert NOE Pilotage System • 4th Generation Crew Station • Brilliant Helicopter Advanced Weapons (BHAW) • Subsystems Technology for IR Reductions (STIRR) ***Advanced Platforms*** • Advanced Rotorcraft Transmission (ART-II) • Helicopter Active Control Technology (HACT) • 3rd Generation Advanced Rotors Demonstration (3rd GARD) • Survivable, Affordable, Repairable Aircraft Program (SARAP) • Aircraft Systems Self-Healing (ASSH) • Multirole Mission Adaptable Air Vehicle (MRMAAV) • Structural Crash Dynamics M&S (SCDMS) • Rotary Wing Structures Technology (RWST) • Advanced Rotorcraft Aeromechanics Technologies (ARCAT) ***Propulsion*** • Integrated High Performance Turbine Engine Technology (IHPTET) Joint Turbine Advanced Gas Generator (JTAGG) • Alternate Propulsion Sources ***Logistics/Maintenance*** • Survivable, Affordable, Repairable Airframe Program (SARAP) • On-Board Integrated Diagnostics Systems (OBIDS) • Subsystems Technology for Affordability and Supportability (STAS)

AIRCRAFT SYSTEMS/ SYSTEM UPGRADES/ADVANCED CONCEPTS	
System • RAH-66 Comanche ***System Upgrade*** • AH-64 Apache Longbow • UH-60 Blackhawk	***Advanced Concepts*** • Enhanced AH-64 Apache • Improved Cargo Helicopter (ICH) • Joint Transport Rotorcraft (JTR)

Figure III-D-1. Roadmap for Army Aviation



S/SU/ACs and provide the opportunity for technology upgrades of fielded systems. These demonstrations are designed to establish a "proof-of-principle," i.e., to serve as a test bed, validate feasibility, and reduce cost and risk for entering engineering and manufacturing development (EMD). The roadmap shows two "technology insertion windows" which offer opportunities for technology application to aircraft S/SU/ACs. Technology insertions which may occur through modification programs for fielded systems, such as AH-64 Apache, UH-60 Blackhawk, CH-47 Chinook, OH-58D Kiowa Warrior, and SOA, are not shown.

The following subsections provide descriptions of the Aviation demonstrations categorized on the roadmap as Mission Equipment, Advanced Platforms, Propulsion, and Logistics/ Maintenance.

a. Mission Equipment

Rotorcraft Pilot's Associate (RPA) Advanced Technology Demonstration (ATD) (93-99). The primary thrust of the Aviation S&T mission equipment area is the RPA ATD. The objective of this program is to establish revolutionary improvements in combat helicopter mission effectiveness through the application of artificial intelligence for cognitive decision aiding and the integration of advanced pilotage sensors, target acquisition, armament and fire control, communications, cockpit controls and displays, navigation, survivability, and flight control technologies. Next generation mission equipment technologies will be integrated with high speed data fusion processing and cognitive decision aiding expert systems to achieve maximum effectiveness and survivability for our combat helicopter forces.

This increased system effectiveness will enable Army Aviation to be more responsive to battle commanders at all levels. RPA will expand aviation's freedom of operation, improve response time for quick reaction and mission redirect events, increase the precision strike capability for high value/short dwell-time targets, and increase day/night, all weather operational capability. RPA will contribute greatly to the pilot's ability to "see and assimilate the battlefield" in all conditions; to rapidly collect, synthesize, and disseminate battlefield information; and to take immediate and effective actions. These developments will enable the full use of the crew's perceptual, judgmental, and creative skills to capitalize on their own strengths and to exploit the adversary's weaknesses.

The Defense Simulation Internet (DSI), through the Army's Battlefield Distributed Simulation—Developmental (BDS-D) program capabilities, will be utilized in the RPA program to perform Measures of Performance (MOPs) validation. The RPA ATD will achieve the following quantitative MOPs relative to Comanche-like performance during 24-hour, all weather battlefield conditions: 30 to 60 percent reduction in mission losses, 50 to 150 percent increase in targets destroyed, and a 20 to 30 percent reduction in mission timelines. Flight test experiments conducted during the RPA program will provide a measure of simulation validation, evaluate the impact of real world stimulus, and provide the confidence that technologies are ready to transition into systems, system upgrades, and advanced concepts. **Supports:** Comanche, Apache, SOA, Army Airborne Command and Control System (A2C2S), dual use potential.

Advanced Helicopter Pilotage (AHP) Technology Demonstration (94-98). The Advanced Helicopter Pilotage technology demonstration supports the RPA ATD. The AHP TD will develop and demonstrate a night/adverse weather pilotage system to visually couple the pilot to the terrain flight environment using advanced thermal and image intensifier sensors and a very-wide-field-of-view, helmet-mounted display. The AHP display system will provide current and future Army aircraft with increased safety and situational awareness, reduced pilot cognitive workload, increased mission launch rates, and enhanced terrain flight operations. **Supports:** RPA ATD, Comanche, Apache, and SOA.

Battlefield Combat Identification (BCID) ATD (93-98). This ATD will demonstrate target ID techniques together with situational awareness information which will prevent fratricide during ground-to-ground and air-to-ground engagements. It is discussed in detail in *IEW*, Section F. **Supports:** Scout and Attack Aircraft, ACT/JTR, ICH.

Multispectral Countermeasures (MSCM) ATD (97-99). The purpose of the Multispectral Countermeasures ATD is to develop prototype hardware for an advanced technology, low cost coherent jammer to protect Army helicopters from imaging infrared surface-to-air missiles.

The integration of a missile detector, high accuracy point/track subsystem, and an IR laser with fiber-optic coupling and advanced expendables will be demonstrated. A multi-line or wavelength agile source will be used to improve its effectiveness against missiles with counter-countermeasures and to develop a capability against infrared imaging seekers. **Supports:** All fielded aircraft and ICH.

Integrated Situational Awareness and Countermeasures (ISACM) Technology Demonstration (00-02). This TD will demonstrate integrated RF/IR/IO Laser Electronic Combat Suite for situational awareness, targeting, and protection against multispectral missiles and smart munitions. Geolocate emitters 1 percent of range, 98 percent of effectiveness vs. advanced SAMs and ATG. **Supports:** ICH.

Air/Land Enhanced Reconnaissance and Targeting (ALERT) ATD (97-00). The purpose of this ATD is to demonstrate automatic target acquisition and enhanced target identification via a 2nd generation FLIR/Multifunction Laser Sensor suite for rapid wide area surveillance and targeting. ALERT will leverage ongoing Air Force and DARPA developments for search on-the-move Aided Target Recognition. Second Generation FLIR and multifunction laser data will be fused to allow large search areas to be covered with high targeting accuracy while at low depression angles and high platform motion. Range profiling of the highest priority targets will provide target identification. **Supports:** Comanche and Apache Improvements.

I2/FLIR Fusion Pilotage Technology Demonstration (00-03). This TD will demonstrate image fusion upgrades to the baseline Comanche dual spectrum (I2/IR) pilotage system to increase mission effectiveness and survivability for future high performance rotorcraft. Knowledge-based image fusion algorithms will significantly enhance image resolution and will support concurrent demonstration of aided nap-of-the-earth pilotage technology. **Supports:** Future Comanche/Apache Upgrades.

Future Missile Technology Integration (FMTI) Technology Demonstration (94-98). FMTI TD will demonstrate the integration on a rotorcraft of a lightweight, fire-and-forget, multi-role missile system for air-to-air and air-to-ground engagements. It includes the integration of command guidance, control, propulsion, airframe, and warhead technologies capable of performing in high clutter/obscurants, adverse weather environments, and under countermeasure conditions. Missile control and guidance system technology will explore capabilities such as lock-on before/lock-on after launch, fire-and-forget, command guidance, signal and image processing, and wide band secure data links. Demonstrated missile system performance (i.e., weight, range, kill ratio, speed, lethality) will be optimized to exceed current baseline parameters of air-to-air Stinger, air-to-ground Hellfire, ground-to-ground Tube-Launched, Optically Tracked, Wire Command-Link Guided (TOW), and ground-to-air Stinger. **Supports:** HMMWV, M2 Bradley, follow-on to TOW, Block II Stinger, Hellfire III, EFOGM.

Survivability/Lethality Advanced Integration in Rotorcraft (SLAIR) Technology Demonstration (00-04). The SLAIR TD will integrate, simulate, and flight demonstrate the next generation mission equipment technologies necessary for attack and scout helicopters to fight effectively and survive in Force XXI. Candidate technologies under development by many RDECs include advanced weapon technology (lelthal and non-lethal), automatic target acquisition/combat identification, advanced fire control, survivability, C3, and the next generation of cognitive decision aiding beyond the RPA. The SLAIR TD will synergistically demonstrate the capabilities of combat versatility, tailorable kill levels, reduced engagement timelines, increased survivability, and reduced fratricide. **Supports:** AH-64D Apache Longbow Modernization, RAH-66 Comanche, potential improvement to Marine AH-1W Super Cobra, dual-use potential (non-lethal).

Low Cost Precision Kill (LCPK) Air-to-Ground, Ground-to-Ground (ATG/GTG) 2.75-inch Guided Rocket Technology Demonstration (96-98). The LCPK ATG/GTG 2.75-inch Guided Rocket TD seeks to demonstrate, through hardware in the loop (HITL) simulation, a low-cost, standoff range, precision guidance and control package for the 2.75-inch rocket. In current operations, large numbers of unguided 2.75-inch rockets would be required to achieve high probability of kill against point and non-heavy targets at standoff ranges, resulting in unacceptable collateral damage and creating a significant logistics burden. With the addition of a retrofit guidance and control package, accuracy comparable to current guided munitions can be obtained. This greatly improved accuracy will reduce the number of rockets required to defeat non-heavy armor point targets by up to 2 orders of magnitude, thereby providing a 4:1 increase in stowed kills at one-third the cost compared to current guided missiles. **Supports:** 2.75-inch Rocket System, Future Missile Systems, AH-64 Apache, OH-58D Kiowa Warrior, SOF Avenger, Bradley Fighting Vehicle, HWMMV, AWIP TD.

Low Cost Precision Kill (LCPK) Airborne Technology Demonstration (99-01). The LCPK Airborne TD will flight demonstrate the helicopter integration of the LCPK 2.75-inch guided rocket. The LCPK technology, developed to meet the objectives of the LCPK STO, will be evaluated from a helicopter system perspective to assure aircraft compatibility and performance effectiveness. **Supports:** AH-64 Apache Longbow Modernization, RAH-66 Comanche, and OH-58D Kiowa Warrior.

Brilliant Helicopter Advanced Weapons (BHAW) TD (06-10). The BHAW TD will integrate and demonstrate, through simulation and ground/flight test, future combined arms interoperable advanced aviation weapons, target acquisition and fire control technologies, and aviation platforms and will quantify resulting increases in aviation mission effectiveness. Full spectrum lethality will be demonstrated from "less than lethal" tailorable up to conventional lethal kill mechanisms. Technology candidates for the BHAW TD include:

- Low cost precision kill weapons with low collateral damage, including brilliant missile technology with immunity to countermeasures.
- Innovative "less than lethal" kill mechanisms, such as directed energy techniques, that immobilize or disrupt personnel, vehicles, or other equipment.
- Advanced auto cannon technologies, e.g., cased-telescoped, bursting munitions, electrochemical and electromagnetic propulsion, electrostatic proximity fuses, closed-loop fire control.
- Automatic target acquisition, recognition, and covert ID using multi-data/sensor fusion of advanced on- and off-board distributed target acquisition concepts.
- Intelligent fire and flight control, 360-degree aircraft aspect that provides quick reaction precision kill with tailorable lethality level and selectable automatic engagement feature.

Supports: Comanche and Apache.

Rotorcraft Air Combat Enhancement (RACE) Technology Demonstration (00-04). The probability is increasing that Army helicopters will encounter airborne threats in future conflicts. There is a need to develop an air-to-air capability for Army aviation to defeat the threat and protect itself and friendly forces. The RACE TD will develop, integrate, and airborne demonstrate the technologies necessary for the Army's existing and future helicopters to meet the need. Technology candidates include improvements to gun, rockets/missiles, target acquisition and fire control systems, and other aircraft system technology necessary to achieve an air-to-air system solution. **Supports:** AH-64D Apache Longbow Modernization and RAH-66 Comanche.

Full Spectrum Threat Protection Technology Demonstration (02-05). This TD demonstrates balanced integration of rotorcraft survivability for the most effective combinations of active countermeasures and susceptibility reduction features for full spectrum, i.e., radar, acoustics, infrared, and visual. It will demonstrate survivability against advanced threat sensors and smart weapons and munitions. The survivability codes will be validated and verified by installing equipment on aircraft with known signature and flight testing against various threats. Enhanced survivability and system performance features for aircraft, to include S/SU/ACs and UAVs, tailored for specific warfighting situations by minimizing weight and aerodynamic impact while maintaining low observable cross section, minimizing threat detection of active countermeasures, increasing jammer effectiveness, optimizing mission routes and tactics, and reducing production costs. **Supports:** TRADOC Battle Labs, Force XXI, Project Reliance, and Multi-Service applications.

Covert Nap-of-the-Earth (NOE) Pilotage System Technology Demonstration (02-05). This TD will demonstrate an advanced, effective, and highly integrated rotorcraft pilotage system to operate covertly NOE and unobstrusively in urban areas with increased survival in hazardous flight environments or emergency situations with reduced crew workload during day, night, and adverse weather. Reduced crew workload, aided precision flight path control, and increased safety will enable crew members to focus on mission level functions while maintaining full vehicle and flight path control. The TD will demonstrate a comprehensive air vehicle management system for pilotage; a large-scale integrated mission equipment suite; automated protection from obstacles, terrain, and other inflight hazards; and increase capability for rotorcraft operations avoiding and using obstacles, terrain and threats for military operations; and increased safety for military and commercial rotorcraft operating in hazardous flight environments. **Supports:** JTR, ICH, Enhanced Apache, far-term manned and unmanned rotorcraft.

4th Generation Crew Station Technology Demonstration (04-07). This TD will demonstrate the next generation of air vehicle crew station architecture. The effort will develop/incorporate advanced displays for full glass cockpit/crew station; three-dimensional display technology; selectable touch, cyclic grip cursor, or pupil tracked cursor information access capability; rapid pilot-reconfigurable information layout on displays; automated artificial intelligence (AI) "Advisor" aiding; intelligent, adaptive interfaces; advanced selectable "windowless" cockpit synthetic vision systems; advanced information display symbology; and advanced flight control designs. Displays, AI, and crew station technology from Air Force, Navy, and NASA programs will be incorporated into system design. The TD will demonstrate: increased pilot performance and overall mission and reduced pilot susceptibility to injury by laser, directed energy, or other sources in hostile electromagnetic environments. **Supports:** JTR, ICH, Enhanced Apache, MRMAAV TD, and advanced ground vehicle crew stations.

Subsystems Technology for Infrared Reductions (STIRR) (97-01). The focus of STIRR is IR technology development, integration, and demonstration to improve the survivability of Army rotary-wing vehicles. The primary goal of increased survivability will be addressed via aggressive efforts to synergistically reduce the thermal emissions from helicopter airframes while developing and improving systems designed to cool plume and engine contributors. STIRR will achieve development of advanced, multi-spectral (visual through far-IR) airframe coatings that are compatible with radar absorbing materials/structures and development of state-of-the-art, low cost, lightweight thermal insulative materials. STIRR will support validation of advanced computational aero/thermo M&S tools which will be used to develop innovative engine IR suppression techniques. Additional quantifiable payoffs of passive signature reduction are direct improvements in active countermeasures performance through increased J/S ratios and improved decoy effectiveness. **Supports:** Current and future rotary-wing system upgrades, JTR, Comanche, USAF, USN, and USMC vertical life air vehicles, AH-64, UH-60, RAH-66 upgrades, ICH, other Services fleets.

b. Advanced Platforms

Advanced Rotorcraft Transmission (ART) II Technology Demonstration (97-00). The ART TD incorporates key emerging material and component technologies for advanced rotorcraft transmissions and makes a quantum jump in the state of the art. The ART-II TD will survey the applicable ART-I (completed in FY92) component technologies and proposed concepts and will integrate the more promising ones into selected transmission/drive subsystem demonstrators. Advanced concepts such as split torque, split path, and single planetary transmissions will be considered with advanced material applications/component designs to demonstrate lighter, quieter, threat tolerant, more durable, reliable, and efficient drivetrain subsystems. **Supports:** JTR, ICH, Apache, dual use potential.

Helicopter Active Control Technology (HACT) Technology Demonstration (98-02). The HACT TD will demonstrate a second generation fly-by-light technology and integration of flight control and mission functions into a Vehicle Management System (VMS). Advanced processing for fault-tolerant systems, individual blade/higher harmonic control, smart actuation concepts will be considered. It will demonstrate high bandwidth active control technologies, multimode stabilization, and carefree maneuvering and robust control law design methodologies for affordable high performance helicopter control systems.

The HACT will provide enhanced mission effectiveness during night adverse weather, increased confined or terminal area operations capability, reduced workload, and improved crew endurance. It will maximize ability of the flight crew to exploit inherent vehicle performance, maintain safety and reliability while improving affordability and O&S costs, simplify maintenance, and reduce fleet attrition. **Supports:** Comanche, Apache, JTR, ICH.

3rd Generation Advanced Rotor Demonstration (3rd GARD) Technology Demonstration (01-04). The 3rd GARD TD will demonstrate advanced rotors/concepts to enhance current performance ceilings through high lift airfoils/devices, tailored planforms and tip shapes, elastic/dynamic tailoring methods, active on-blade control methods, acoustic signature reduction techniques and integration of advanced rotors/concepts with advanced active control systems. 3rd GARD technology will provide for increased survivability via reduced acoustic signature and increased maneuverability/agility, increased rotorcraft speed capability, increased range and payload, reduced O&S cost via reduced vibration and loads. **Supports:** Far-term Advanced Rotorcraft Concepts.

Aircraft System Self-Healing (ASSH) Technology Demonstration (05-07). The ASSH TD will demonstrate a self-healing flight control system for rotorcraft that automaticaly reconfigures remaining air vehicle lift, control, and applicable mission equipment assets to compensate for the degradation of vehicle control when damaged by battle, obstacle strike, or premature subsystem or component failure, and will advise the crew for appropriate action. The TD will demonstrate robust fault detection and identification of critical failures through onboard expert system diagnostics, compensation strategies for damaged aircraft subsystems, and smart flight control component technology. ASSH technology improves the survivability of crew and aircraft by providing a return-home capability for damaged aircraft, reduced aircraft losses, increased operational flexibility, productivity during all mission phases, and mobility of damaged assets. **Supports:** Far-term advanced concepts.

Multirole Mission Adaptable Air Vehicle (MRMAAV) Technology Demonstration (08-11). The MRMAAV TD will demonstrate the feasibility of using a common airframe and power plant(s) to conduct multiple different primary mission roles with the same aircraft with minimal impact on equipment interchanges (e.g., avionics, weapons, survivability packages). Common dynamics and aeromechanics components would be incorporated to support development of manned and unmanned systems. The MRMAAV concept offers battlefield commanders unprecedented mission flexibility to reconfigure aircraft in the field for various mission roles. Fewer numbers of aircraft and crews will be required to perform multiple different missions. **Supports:** Far-term advanced concepts.

Structural Crash Dynamics Modeling and Simulation (SCDMS) Technology Demonstration (97-00). SCDMS will establish a structural crash dynamics modeling and simulation (M&S) capability from a single selected off-the-shelf computer code that can satisfy the need for a design and performance evaluation tool to be optimized for helicopter crashworthy systems or materials, and for scenarios common to helicopter crashes. A uniform standard approach to computer modeling of global helicopter crash dynamics will be established. SCDMS will utilize ARL-VSD (NASA LaRC) modeling and testing expertise in support of the four-phase effort, evaluating state-of-the-art M&S codes to determine strengths and weaknesses and to select code with most strengths. **Supports:** ICH.

Rotary Wing Structures Technology (RWST) (97-01). RWST will fabricate and demonstrate advanced lightweight, tailorable structures and ballistically tolerant airframe configurations that incorporate state-of-the-art computer design/analysis techniques, improved test methods, and affordable fabrication processes. The technology objectives are to increase structural efficiency by 15 percent, improve structural loads prediction accuracy to 75 percent, and reduce costs by 25 percent without adversely impacting airframe signature. **Supports:** Battle Labs, JTR, ICH, UH-60 upgrades, collaborative technology.

Advanced Rotorcraft Aeromechanics Technologies (ARCAT) (97-00). ARCAT will develop and demonstrate critical technologies in rotorcraft aeromechanics to contribute to enhanced warfighting needs for fielded and next generation systems. Research and development will be conducted to achieve technical objectives by increasing maximum blade loading, increasing rotor aerodynamic efficiency and adverse forces, reducing aircraft loads and vibration loads, reducing acoustic radiation, increasing inherent rotor lag damping, and increasing rotorcraft aeromechanics predictive effectiveness. Achievement of aeromechanics technology objectives will contribute to rotorcraft system payoffs in range, payload, cruise speed, maneuverability/agility, reliability, maintainability and reduced RDT&E, procurement, and O&S costs. **Supports:** Battle Labs, Force XXI.

c. Propulsion

Integrated High Performance Turbine Engine Technology (IHPTET) Program [Joint Turbine Advanced Gas Generator (JTAGG)] Demonstration (91-03). JTAGG is a tri-Service effort which is structured to be compatible with the goals of the IHPTET initiative. IHPTET is a three-phased tri-Service/DARPA/NASA effort with major milestones in 1991, 1997, and 2003. The JTAGG I+ was completed in 1994. Specific JTAGG I+ goals included a 25 percent reduction in fuel consumption and a 60 percent increase in power-to-weight ratio. Follow-on JTAGG II and III efforts are addressing the 1997/2003 IHPTET goals. A full engine demonstration of the improvements in gas turbine technology resulting from the JTAGG program will be conducted as required to be compatible with S/SU/AC requirements. Results will be improvements in performance, efficiency, and power-to-weight ratio over current production engines. The demonstration will incorporate advanced materials and materials processing, simulation and modeling, computational fluid dynamics, and manufacturing science. **Supports:** JTR, ICH, Apache, all rotorcraft, dual use potential.

Alternate Propulsion Sources (APS) Technology Demonstration (04-10). The APS will explore advanced propulsion concepts beyond air-breathing propulsion. This program will consist of proof-of-principle technology demonstrations for propulsion concepts with potential application initially to a UAV with VTOL capability. The technology focus will explore the potential of utilizing such power sources as solar, high power microwaves, fly wheel generators, and hybrids. **Supports:** UAV application.

d. Logistics/Maintenance

Survivable, Affordable, Repairable Airframe Program (SARAP) Technology Demonstration (05-08). SARAP will develop, integrate, and demonstrate efforts to provide efficient and affordable airframe structures, diagnostic and repair concepts that address tolerance to such high intensity combat threats as NBC, DEW, mines, and ballistics to improve survivability, performance, durability, sustainability, and serviceability of current and future VTOL aircraft. Emerging technologies in materials, smart structures, manufacturing methods, diagnostics, and tools will be used to the fullest to obtain optimum hardening and repairability. SARAP will use Integrated Product and Process Development (IPPD), concurrent engineering, virtual prototyping, and synergistically integrated technologies to the maximum extent practicable. Some of the overall enhancements to be realized include a 50 percent improvement in high intensity conflict survivability, a 30 percent reduction in repair times, and a 60 percent increase in aircraft combat life. **Supports:** Far-term advanced concepts and material changes to fielded systems.

On-Board Integrated Diagnostic Systems (OBIDS) Technology Demonstration (00-04). The OBIDS is a showcase platform to demonstrate advanced diagnostics and prognostics. Technologies to measure, track, and analyze aircraft vibrations, stresses, pressures, temperatures, and other critical parameters necessary to assess aircraft and subsystem health and usage and will be integrated into the airframe. These improved diagnostic and prognostic capabilities will be measured for O&S cost benefits and enhanced aircraft safety. The man-machine interfaces needed to present data and generate information leading to corrective maintenance and early failure detection will be a principal focus. Technology demonstrations may encompass the design and integration of systems needed to promote the health and proper functioning of structures and dynamic components. Emphasis will be placed on improvements in maintainability and availability. **Supports:** All aircraft SU/AC.

Subsystems Technology for Affordability and Supportability (STAS) (97-00). The focus of STAS is on those subsystems technologies directly affecting the affordability and supportability of Army Aviation. It addresses technical barriers associated with advanced, digitized maintenance concepts, and real-time, on-board integrated diagnostics. The expected benefits from STAS are reductions in Mean Time to Repair (MTTR), No Evidence of Failure (NEOF) removals, and spare parts consumption resulting in overall reductions in system life cycle cost and enhanced mission effectiveness. Pursuits include on-board as well as ground-based hardware and software concepts designed to assist the maintainer in diagnosing system faults and recording and analyzing maintenance data and information. On-aircraft technologies will include advanced diagnostic sensors, signal processing algorithms, high density storage, and intelligent decision aids. Shipside diagnostic and maintenance actions will integrate laptop and body-worn electronic aids, advanced displays, knowledge-based software systems, personal viewing devices, voice recognition technologies, and tele-maintenance networks. **Supports:** Battle Labs, AH-64, UH-60, RAH-66 upgrades, ICH, JTR, other Services, and civil rotorcraft fleets.

5. Relationship to Modernization Plan Annexes

The versatility and importance of Army Aviation as a member of the combined arms team will play a vital role in the Army's future modernization plans. The linkage of aviation S/SU/ACs to other Army Modernization Plan Annexes is shown in Figure III-D-2.

Figure III-D-2. Correlation Between Army Aviation S/SU/ACs and Other Army Modernization Plan Annexes

AVIATION Systems/System Upgrades/Advanced Concepts		MODERNIZATION PLAN ANNEXES: Mounted Forces	Close Combat Light	Soldier Systems	Air Defense Artillery	IEW	C4	Fire Support
System	RAH-66 Comanche	●	●	○	●	●	●	○
System Upgrade	AH-64 Apache Longbow	●	●	○	●	●	○	○
	UH-60 Blackhawk	●	●	○	●	●	○	○
Advanced Concepts	Improved Cargo Helicopter (ICH)	●	●	○				○
	Enhanced AH-64 Apache	●	●	○	●	●	○	○
	Joint Transport Rotorcraft (JTR)		●	○	○			○

● System plays a significant role in the Modernization Strategy

○ System makes a contribution to the Modernization Strategy.

E. Command, Control, Communications, and Computers (C4)

In future conflicts, information technologies will play a critical role in achieving the dominance we seek. That presents several challenges. We must develop the communications, sensors, and computing systems to capture, synthesize, and distribute near-real-time information to all levels of operations.

William J. Perry
Secretary of Defense

1. Introduction

The United States Army is vigorously marching towards modernizing and enhancing current command and control, communications, and computer (C4) capabilities to meet the needs of all warfighters. C4 modernization is critical to the Army's modernization objectives, information superiority, and battlespace dominance. The Army's C4 S&T program is directed towards providing the technologies, architecture, protocols, standards, algorithms, and software for integrating communications assets throughout the battlefield. The emphasis is placed on establishing a C4 substructure of the digitized battlefield to provide mission planning with optimal use of resources throughout the task force. Electronic maps, resource data, intelligence information, and operational procedures are used to achieve highly automated operational planning, rehearsal, and execution with real-time command and control. Overall, Army C4 systems are currently rated as having limited capability or quantity to achieve modernization objectives. Communication architectures that will improve and enhance existing capabilities are not yet fielded to the warfighter. To overcome these deficiencies, the future of C4 has been mapped along a path for the modernization of the Force of the 21st Century, i.e., "Force XXI." The Army's C4 modernization and strategic planning efforts are an integral part of *Force XXI* and are critical to achieving the *Joint Chief's Vision 2010*. The synchronization of C4 modernization through Force XXI, Vision 2010, and the Battle Labs/Battlefield Dynamics will allow America's Army to be the best in the world, trained and ready for Victory.

2. Relationship to Operational Capabilities

Table III-E-1 shows detailed C4 system capabilities, noting whether they are near term (System Upgrade capabilities) or far term (Advanced Concept capabilities). Command and Control (Force Level and Lower Echelon) and Communications (Mobile, Local, Wide, and Range Extension) are the capstones of Army C4 modernization. The foundations for these SU/AC functional areas are Computing and Software and Modeling and Simulation technologies.

3. Army C4 Modernization Strategy

Army C4 modernization efforts support all of the Army's modernization objectives as defined in the 1996 Army Modernization Plan. The objectives represent a combined modernization strategy that improves and/or enhances existing capabilities and takes advantage of "leap ahead" technologies. Army Modernization considers Force XXI as the Army's corporate goal of what it must become to remain the lethal force of decision through the early decades of the 21st century. It embraces the tenets of Doctrinal Flexibility, Strategic Mobility, Tailorability and Modularity, Joint, Multinational and Interagency Connectivity, and Versatility. The Warfighter Information Network (WIN), in conjunction with the Battlefield Information Transmission System (BITS), will provide the communications infrastructure for Army C4 modernization. The purpose is to provide an integrated "foxhole to sustaining base" warfighter information network consisting of communications and information services that support Force XXI requirements well into the 21st century. Significant emphasis is being placed on leveraging and adapting commercial internet technology and protocols.

Table III-E-1. Command, Control, Communication, and Computer System Capabilities

SU/AC FUNCTION	BATTLEFIELD DYNAMICS: Early Entry	Depth and Simultaneous Attack	Mounted Battlespace	Dismounted Battlespace	Battle Command	Combat Service Support	SYSTEM/SYSTEM UPGRADE CAPABILITIES	ADVANCED CONCEPT CAPABILITIES
COMMAND AND CONTROL ***System Upgrade*** Force Level Lower Echelon ***Advanced Concept*** Force XXI/Vision 2010	● ● ●	● ● ●	● ● ●	● ● ●	● ● ●		• Integrated Force Management • Forecasting, planning, and resource allocation • Platform embedded C2 • Distributed, relational data base (large area, low resolution) • Auto situation map update • Replicated data bases • Intel order generation • Nodal security • Software bridge between diff sys • Auto comm interface • Expert System battle planning - Resource allocation - Concept of operation • Expert System info correlation and fusion • Distributed data base with real- time updating • Interface with ABCS • Adaptive distributed processing • Voice I/O • Battlefield visualization • 3-D mission planning • Consistent battlespace understanding	• Distributed situation assessment • Knowledge-based info presentation • Distributed empowerment • Interoperability with joint assets • Flexible hierarchical data base for multi-resolution, multiscales • Multimodal command understanding • Intel msg preparation • Expert systems - Decision aids, management sys - Wargaming/simulation • Distributed processing/data bases • Multimedia storage & retrieval • Multimedia presentation & interface • Multilevel security • Built-in training • Interoperability to lower echelons • C2-on-the-move • Enhanced situation awareness • Fault-tolerant processing at critical nodes • Synchronized battle management • Sensor integration • Distributed processing • Integrated POS/NAV • Head-up display • Automated mission planning
COMMUNICATIONS ***System Upgrade*** Mobile Wide Area Local Area Range Extension ***Advanced Concept*** Force XXI/Vision 2010	● ●	● ●	● ●	● ●	● ●	● ●	• Systems control - Co-site interference reduction - Embedded COMSEC - Frequency management • ECCM enhancements • Gateways between local, wide area, and mobile systems • Multilevel security • Fiber optic LAN • Data/voice transport • EHF satellite communications • Light satellite • Tactical Multinet Gateways • RPV Communications Relay • Internet Controller • Surrogate Satellite • Enhanced data protocols • Conformal antennas • Mobile satellite connectivity • Personal Communications System • ATM switching • Battlefield information transmission • Universal transaction communications • Assured communications	• Distributed systems • Dynamic rerouting • Intelligent switches • Controllable signatures • Wireless LAN • Wideband multimedia communications • Integrated COMSEC • User transparent • Cellular satellite systems • Common user/satellite trunking • Airborne relay (surrogate satellite) • Multiband multipurpose radios • Transparent connectivity to local, wide, range ext systems • Anti-jam EHF • OTM DSCS • Militarized satellite PCS • Wideband RAP OTM SATCOM • DIS compliant architecture • Real-time OTM planning tools • A comprehensive warfighter information network • Universal transaction services

● Provides Significant Capability   O Provides Some Capability

4. Roadmap for Command, Control, Communications, and Computers

Table III-E-2 is a summary of demonstrations and system upgrades/advanced concepts (SU/ACs) displayed on the Roadmap (Figure III-E-1) for C4 Modernization. The evolution of battlefield C4 into the 21st century begins with current C4 systems as a baseline. In order to preserve current investments, a step-by-step block improvement approach to modernizing legacy systems is utilized. ATDs and ACTDs support the development of SU/ACs. The flow of C4 modernization appears on the roadmap beginning with Command and Control and Communications system upgrades on the far left, followed by specific ATDs, ACTDs, and Technology Demonstrations leading to Force XXI.

a. Technology Programs Leading to Command and Control Modernization

This past year, the Combined Arms Command and Control (CAC2) ATD was completed. It was successful in demonstrating command and control functionality and shared situational awareness for brigade and below, to include Armor, Aviation, Mounted Forces, and Fire Support. This ATD forms the baseline for addressing some key command and control (C2) and operational battlefield dynamic issues. The following ATDs and technology demonstrations represent the Army's investment in modernizing its C2 capabilities.

Rapid Battlefield Visualization (RBV) ACTD (97-01). The goal of this ACTD is to demonstrate capabilities to collect source data and generate high resolution digital terrain data bases quickly to support crisis response and force projection operations within the timelines required by the Joint Force Commander. The Commander will be capable of integrating terrain data bases with current situation data, and can therefore manipulate and display the integrated databases in order to determine how to achieve operational objectives and visualize a desired end state. Source data collection, digital terrain database generation and tailoring, database dissemination, and applications software will be integrated and evaluated. **Supports:** JPSD/RFPI, Force XXI, and Vision 2010.

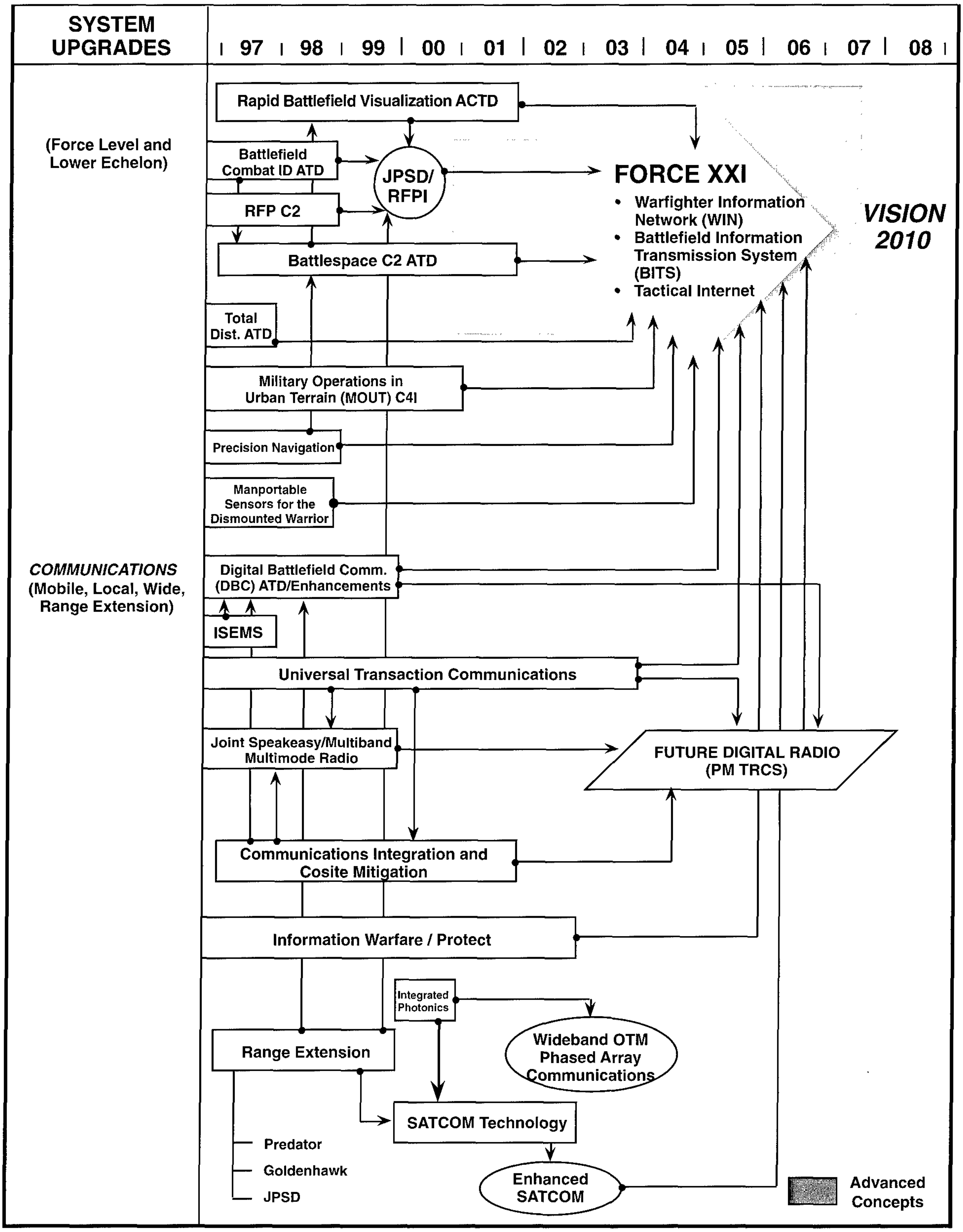
Battlefield Combat Identification (BCID) ATD (93-98). The BCID addresses the mission need to develop effective and survivable ground-to-ground and air-to-ground combat identification capabilities to enhance warfighting

Table III-E-2. C4 Demonstration and System Summary

ATDs	TECHNOLOGY DEMONSTRATIONS
• Battlefield Combat ID (BCID) (see *IEW*) • Digital Battlefield Communications (DBC) • Total Distribution (TD) (see *Logistics*) • Battlespace C2 (BC2) **ACTD** • Rapid Battlefield Visualization (See Volume II, Annex B, for further information.)	***Command and Control*** • Rapid Force Projection C2 • MOUT C4I • Advanced Manportable Sensors for the Dismounted Warrior • Precision Navigation ***Communications*** • Communications Integration and Cosite Mitigation • Speakeasy Multiband Multimode Radio (MBMMR) • Range Extension • Improved Spectrum Efficiency Modeling and Simulation (ISEMS) • Universal Transaction Communications • Information Warfare/Protect • Integrated Photonics • SATCOM Technology

SYSTEM UPGRADES AND ADVANCED CONCEPTS	
System Upgrades	***Advanced Concepts***
• Command & Control - Force Level • Command & Control - Lower Echelon • Communications - Mobile • Communications - Local Area • Communications - Wide Area • Communications - Range Extension	• Force XXI (Vision 2010)

Figure III-E-1. Roadmap for C4 Modernization



capabilities and avoid engagement of friendly forces and noncombatants. The approach is based on a two-pronged concept that develops both positive Target Identification (TI) and Situation Awareness (SA) capabilities. It integrates both TI and SA at different echelons starting at the individual platform level. The PM-CI/PEO IEW owns this project. Management responsibilities lie with the U.S. Army Communications-Electronics Command (CECOM), Night Vision/Electronic Sensors Directorate (NVESD). Further details on the BCID ATD may be found in Section F, *IEW*. **Supports:** Battlespace C2, Aviation platform upgrades, JPSD/RFPI, Force XXI.

Rapid Force Projection Command and Control (RFP C2) Technology Demonstration (95-98). This program will develop the command and control element for the RFPI ACTD. It consists of a reconfigurable Light Tactical Operation Center Testbed (LT2) and multiple communications interfaces. Digitized systems will link all battlefield elements from the individual soldier through the brigade while preventing communications systems information overload. The RFP C2 demonstration will provide real-time to near-real-time integration of ACTD task force "hunters," "killers," and organic weapons; commanders; and battlefield functional area (BFA) battlefield operating systems (BOS), i.e., ASAS and AFATDS. The LT2 will support target analysis, weapon-target pairings, engagement control, EFOGM fire direction, organic sensor management, commander's situation awareness, battle damage assessment, hunter-killer mission planning, near-real-time data fusion, vertical integration of command levels, and horizontal integration with other functional elements (i.e., intelligence, field artillery, air defense, armor, dismounted soldier). **Supports:** Force XXI.

Battlespace Command and Control (BC2) ATD (97-01). This ATD will develop and demonstrate information and knowledge based technology capabilities including provision of a common, integrated situation display with selectable detail and resolution providing battlefield visualization and supporting systems architectures. The BC2 ATD includes: intelligent agents for information retrieval, filtering, and deconfliction; intelligent products to support decision making; and development of systems architecture. Tri-Service C2 sources will be partitioned and distributed automatically across an integrated network of communications and computer medium to provide real-time targeting, target hand-over, mission planning, route planning, friendly and enemy picture. The BC2 multi-Service system architecture will interoperate with multiechelon Joint/Allied assets providing faster, more accurate, more intuitive, tailored battlespace information to the mobile strike force and Force XXI. This ATD is also an integral part of Defense Technology Objectives (DTOs) for Consistent Battlespace Understanding, Forecasting, Planning, and Resource Allocation, and Integrated Force Management. **Supports:** Force XXI, RBV ACTD.

Total Distribution ATD (95-97). The success of the Log Anchor Desk (LAD) in satisfying the logistics user's needs for decision support software, coupled with the advances made in the Common Operating Environment (COE) and in the architecture of the command and control system, has resulted in a merger of the LAD efforts with the Total Distribution (TD) ATD. The goal of the merger is to continue the development of the functionality of the LAD while integrating it with data sources as they are developed and integrated into the C2 system's architecture. For further details, see *Logistics*, Section O. **Supports:** Force XXI.

Military Operations in Urban Terrain (MOUT) C4I Technology Demonstration (96-00). The goal is to demonstrate robust, scalable C4I and advanced sensor capabilities that provide commanders and warfighters with seamless, nonhierarchical adaptive networks for multimedia communications in a highly dynamic MOUT environment. The objective is to evolve an integrated communications infrastructure that leverages commercial protocols, formats, waveforms, and standards to achieve global tri-Service interoperability through integration of mobile IP tactical networks into global infrastructure. MOUT C4I will demonstrate near-real-time vertical and horizontal command and control from the battalion down to the individual combatant. **Supports:** Force XXI Land Warrior.

Advanced Manportable Sensors for the Dismounted Warrior Technology Demonstration (94-98). This effort will develop and demonstrate optimum components and integration of thermal imagery, laser rangefinder, electronic compass, and near IR pointer into a compact sighting system. Imagery and data will be output to the Land Warrior head mounted display and soldier's computer. These technologies will provide the soldier with extended range and automated targeting capabilities. Further details are found in *Soldier*, Section I. **Supports:** Lightweight Laser Designator/Rangefinder, Force XXI Land Warrior.

Precision Navigation (94-98). This program provides accurate, robust, worldwide positioning through Global Positioning System (GPS) enhancements, advanced navigation sensors, and digital terrain data bases using advanced algorithms and integration concepts. The intent is to make maximum use of an integrated GPS capability while conducting nap-of-the-earth flight and precision approach/landing demonstrations as well as improving pos/nav capabilities of soldier and ground-based platforms. Precision Navigation integrated with a high integrity digital terrain data base provides the capability required to demonstrate platform positioning accuracies of 1 to 3 meters, enhancing situation awareness in all environments. **Supports:** Digitization of the Battlefield, Navigation Warfare, Battlespace C2, Precision Strike, RPA, Comanche, Soldier system upgrades, and Ground and Air Vehicles.

b. Technology Programs Leading to Communications Modernization

Communications, specifically seamless communications, facilitates command and control. Command and Control would be impossible without the ability to communicate, i.e., transmit and receive strategic, tactical, and operational information in a timely manner to the Commander and associated staff. Several 6.2 programs are under way to facilitate and implement Army 6.3 communications efforts, including a Personal Communications System, Antennas for Communications Across the Spectrum, and Advanced Modeling and Simulation. Please refer to Chapter IV for details. The following ATDs and technology demonstrations reflect the Army's current strategic plan for Communications modernization.

Digital Battlefield Communications (DBC) ATD (95-99). This ATD will exploit emerging commercial communications technologies to support multimedia communications in a highly mobile dynamic battlefield environment and will support Digitized Battlefield and split-based operations. It will evolve into an integrated communications infrastructure that utilizes commercial protocols and standards to achieve global interoperability. Commercial Asynchronous Transfer Mode (ATM) technology will be integrated into actual tactical communications networks to provide "bandwidth on demand" to support multimedia information requirements. In order to extend ATM services to forward tactical units, a Radio Access Point (RAP) will be prototyped and tested. The RAP utilizes a high capacity on-the-move trunk radio to feed a variety of mobile subscriber services. Both manned and unmanned aerial platforms will be fitted with wideband relay packages to support on-the-move (OTM) tactical operations, supporting bandwidths of up to 155 Mbps. This ATD will conclude in FY99 with the insertion of appropriate technology products (high capacity digitized communications and split-based operations) in CORPS XXI AWE. A parallel effort, DBC Enhancements (96-99), includes an earlier demonstration of the Direct Broadcast Satellite (DBS) technology (in support of JWID 96 and Task Force XXI). An effort to exploit terrestrial PCS was added to the program at the request of the Army Digitization Office, and will be used to exploit commercial CDMA and BCDMA technology as a wireless PBX off an MSE switch for command post voice and data subscribers. Multilevel security requirements for Force XXI will be addressed by the insertion of Tactical End-to-End Encryption Device (TEED) hardware. Wideband HF technology will be evaluated, tested in the U.S. Army CECOM Digital Integrated Laboratory, and inserted into Division XXI AWE. **Supports:** All Transport Systems, FORCE XXI, Future Digital Radio (FDR).

Improved Spectrum Efficiency Modeling and Simulation (ISEMS) Technology Demonstration (95-97). This program focuses efforts in support of Winning the Information War and Digitization of the Battlefield. The challenge is to develop an enhanced communication modeling and simulation environment that provides real-time, flexible, DIS-compatible, and cost-effective capabilities for resolving complex operational problems. The emphasis is on real-time descriptions of environment phenomena for applications to modeling of dynamic network and communication system performance management, communication equipment characteristics, communications realism and propagation reliability algorithms, spectrum use efficiency, and frequency management techniques. Software capable of modeling communications system capacity and performance and dynamic battlefield environments in support of future global deployment of communication technology will be available in FY97. ISEMS transitions key technologies to BC2, DBC, and other ATDs. **Supports:** DBC and DBC Enhancements.

Universal Transaction Communications Technology Demonstration (96-03). This demo will provide seamless connectivity and integration across communications media. The goal is to provide the commander the ability to exchange and understand information unimpeded by differences in connectivity, processing, or systems interface characteristics. It will allow information to flow from wherever it exists, in whatever form, to wherever it is needed in whatever form it is needed. Attributes include: automated interfaces; techniques for enhancing the commercially available signal conditioning; provision of dynamic profiles and adaptive conditioning; and automatic, adaptive addressing to allow connections to users completely independent of any knowledge of location. **Supports:** All tactical communications and the tactical internet, Force XXI.

Joint Speakeasy/Multiband Multimode Radio Technology Demonstration (95-99). The Speakeasy Multiband Multimode Radio (MBMMR) is a Joint Service Program to develop the baseline architecture and technology for the objective MBMMR, meeting the requirements of the Future Digital Radio (FDR). MBMMR will demonstrate a highly flexible radio architecture, allowing rapid waveform reprogrammabililty/reconfigurability to support the rapidly changing mission requirement of EW threats, interoperability, networking, traffic load, frequency assignment, and general modes of operation. Technology insertion includes the use of advanced digital signal processor (DSPs), programmable four-channel CYPRIS chip INFOSEC modules, and interference cancellation (Cosite) circuitry. The MBMMR will utilize an "open" (industry releasable) system architecture. A highly software reprogrammable (waveform and INFOSEC) radio will provide four simultaneous multiband multimode radio channels, networking functions, and minimize the required number of antennas. **Supports:** Future Digital Radio, Force XXI.

Communications Integration and Cosite Mitigation Technology Demonstration (97-01). The objective of this demonstration is to reduce the size, weight, power, and cosite interference problems that occur when multiple radios in either the same or dissimilar frequency bands are integrated within a communications system. The physical space constraints of mobile platforms cause these problems to be even worse. Technology from ongoing developments will be coupled with new efforts to address the problem within the continuous frequency band from 2 MHz to 2 GHz while also attacking the cosite interference in the HF, VHF, and UHF bands. Development efforts include VHF and UHF multiport antenna multiplexers, ancillary cosite mitigation devices, and wideband linear power amplifiers. Additionally, a multiband communications system will be integrated within a typical Army SICPS shelter mounted on a HMMWV and tests performed to evaluate the resultant performance and enhancements. This testbed will be exercised throughout the FY99-FY01 period, for evaluation of the individually developed items. **Supports:** All mobile multiband communications systems and Force XXI.

Information Warfare/Protect Technology Demonstration (96-02). This program will develop and demonstrate (through experimentation and field testing) techniques for the protection of tactical information systems and communications networks. These techniques will validate Information Security, Information Integrity, Attack Detection, Restoration, and recommend real-time countermeasures to limit network damage. This demonstration will tie together various information systems' protect mechanisms including encryption, AJ/LPI (frequency hopping/direct sequence spreading), error detection/correction, and authentication (both parity and key); and automation protect mechanisms such as virus/malicious code (detection and prevention of infiltration), authentication (parity, digital signature), access control (authorization lists/certificates), security audits, man in the loop, firewalls, and air gaps. Numerous IW protect mechanisms will be used to secure the tested unit's weapons systems against known vulnerabilities. Maximum use of exiting COTS and GOTS software products will minimize R&D of new products. Technology to be used includes secure firewalls, automated intrusion detection and response capabilities trusted operating systems, malicious code detection, and security and analysis tools procedures. **Supports:** Force XXI, JWSTP/Information Warfare.

Range Extension Technology Demonstration (97-99). This program directly supports the Army C4 modernization "key azimuth" of Range Extension through the development and integration of a multitude of SATCOM and related technologies. It will identify and develop key technologies required for airborne applications of a suite of communications packages, design and integrate specific systems, and conduct system tests and demonstrations of intratheater communications range extension at a variety of data rates. Major technology areas to be addressed are airborne payload (including antennas) designs, ground terminal adaptations, interoperability/compatibility, and simulation. These technologies will be used to supplement current (and programmed) SATCOM resources at all frequency bands. SATCOM terminals will be augmented and enhanced to provide the capability of communicating via satellite and/or airborne platforms. The utility of SATCOM terminals will be extended by improvements to reduce size and weight, increasing throughput and mobility and implementing emerging techniques such as Demand Assignment Multiple Access (DAMA). An SHF "Surrogate Satellite System" will be demonstrated in FY98. In FY99, a UAV-based EHF and airborne battlefield paging capability will be demonstrated. **Supports:** JPO UAV TIER II Program, Goldenhawk, and Joint Precision Strike .

Integrated Photonics Technology Demonstration (00). This effort will develop integrated photonic subsystems for application to optical control of single beam phased array antennas and fiber optic point-to-point links, local area networks, and antenna remoting systems. Subsystems will be developed for optical control of multi-beam phased array antennas. These subsystems will reduce size, cost, and power consumption while increasing the performance of high speed fiber optic systems. Demonstration of a photonically controlled multipanel phased array antenna will be conducted during FY00. **Supports:** SATCOM on-the-move.

SATCOM Technology Demonstration (00-02). This technology effort will extend the applications and capabilities of SATCOM terminals by providing higher data rates, improvements in throughput, and reduce life cycle costs. Throughput improvement will utilize emerging techniques and architectures such as DAMA, on a per call basis. Overall improvements to systems and equipment will reduce size and increase mobility for military and commercial SATCOM terminals. **Supports:** SATCOM Upgrades.

5. Relationship to Modernization Plan Annexes

Figure III-E-2 shows the correlation between C4 modernization efforts versus other Army Modernization Plan Annexes. C4 is integral to most of the Army's modernization objectives. In one form or another, C4 facilitates the capability to project, sustain, and protect the Force, Win the Information War, conduct Precision Strikes, and Dominate the Maneuver. The Army's continued pursuit of high-tech, state-of-the-art communications-electronics technologies in support of enhanced C4 capabilities, guarantees the stability of the United States defense posture and the safety of our most valuable asset, the Warfighter.

Figure III-E-2. Correlation Between C4 SU/ACs and Other Army Modernization Plan Annexes

COMMAND, CONTROL, COMMUNICATIONS, AND COMPUTERS—SYSTEM UPGRADES AND ADVANCED CONCEPTS		Mounted Forces	Aviation	Fire Support	Air Defense Artillery	Close Combat Light	IEW	Soldier Systems	Space
		MODERNIZATION PLAN ANNEXES							
System Upgrades	C2 - Force Level			●	○		●		●
	C2 - Lower Echelon	●	○	○		●	●	●	○
	Comm - Mobile	●	●	○	●	●	○	●	○
	Comm - Wide Area			○		○			●
	Comm - Local Area	●	○	●	○	●	○	○	○
	Comm - Range Ext		○						●
Advanced Concepts	Force XXI/Vision 2010	●	●	●	●	●	●	●	●

● System plays a significant role in the Modernization Strategy.
○ System makes a contribution to the Modernization Strategy.

F. Intelligence and Electronic Warfare

Knowledge is Power.

Francis Bacon

1. Introduction

Commanders require dynamic intelligence support, tailored to their specific mission requirements. Intelligence must be timely to enable them to make informed decisions for the simultaneous application of decisive combat power across the depth and breadth of their areas of responsibility. The key to their ability to apply focused and synchronized combat power is a seamless intelligence system of systems that enables them to utilize all of the capabilities of the intelligence community, including national agencies, theater assets, and organic capabilities to see the battlefield and accurately target high payoff enemy targets.

Intelligence (Intel) XXI is the Army Intelligence Vision supporting Force XXI, created to provide intelligence support to warfighters at all echelons, Joint and Ground Component Commanders, and coalition forces, across the continuum of 21st century military operations. This vision provides commanders with a knowledge-based, prediction-oriented, and operationally flexible intelligence system. Intel XXI is focused on intelligence support for the Force Projection Army in the Information Age of the 21st century.

The focus of Intel XXI is on the presentation of intelligence in a way that immediately conveys an understanding of the battlespace and the significance of the intelligence presented. Underlying the focus on presentation is an operationally flexible system executing an expanded intelligence cycle (present, manage, collect, process, and disseminate) in a more rapid and focused way to provide the commander what is needed, when it is needed, melded with his operational plan. The essence of intelligence is the ability to reduce uncertainty and provide an understanding of the battlefield through effective presentation. Intel XXI will enable us to leverage Information Age Technology to do exactly that.

Based upon doctrinal underpinnings, the Army conducted a Force Design Update for both the Active and Reserve component MI force structure. The objective was to create a seamless system of intelligence systems from national to maneuver battalion level. To meet the targeting challenges of the 21st Century, key information and a common view of the battlespace will be sent to all commanders immediately, emphasizing graphic rather than narrative reporting. This integrated battlefield will be visually portrayed throughout its width, depth, and height, with sensor input sufficiently accurate to permit precision targeting.

Counterintelligence (CI) and Human Intelligence (HUMINT) are integral to IEW and contribute to the warfighters' ability to conduct operations by denying information to enemy weapon and information gathering systems, deceiving the enemy regarding the battlefield situation, and developing unprecedented environmental awareness and force protection predictability.

Meeting the warfighters' demands for timely, accurate, and relevant targeting information requires a future intelligence architecture built upon these key modernization concepts. Our goal is:

- One Family of Unmanned Aerial Vehicles to fix targets.
- One Airborne System to look deep.
- One Division Sensor System that does it all.
- One All Source Analysis System that fuses it all.
- One Processor to exploit national capabilities.
- One Common Ground Station to conduct the fight.

The research, development, and fielding of this new generation of intelligence systems is a continuous process. The intelligence force capabilities provided by our modernization program give us a more balanced and capable force. Planned Systems/System Upgrades and Advanced Concepts (S/SU/ACs) will provide the operational capabilities that will ensure our spectrum supremacy and allow us to win the information war.

2. Relationship to Operational Capabilities

In Table III-F-1, detailed IEW system capabilities are summarized; the Systems/System Upgrades column refers to relatively near-term capabilities, the Advanced Concepts column presents far-term goals. Correlation between these system capabilities, the IEW S/SU/ACs, and TRADOC, Battlefield Dynamics is also displayed.

3. IEW Modernization Strategy

The modernization of Army intelligence and electronic warfare systems is discussed in Annex D, IEW, to the *Army Modernization Plan* (AMP). It develops a strategy for an open systems architecture to allow for continuous modernization of the IEW mission area to provide multimission systems on common carriers for a complementary mix of airborne, ground-based, and cross-FLOT sensors, processors, and jammers. The goal of IEW modernization is to provide the Army with the most capable IEW systems in the world, while developing future systems to meet the challenges of the 21st Century.

As noted in the introduction to this section, Intelligence XXI is the intelligence vision that supports Force XXI. Its intent is fundamentally based on the requirement to provide intelligence support to warfighters and Joint and Ground Component Commanders across the continuum of the 21st century military operations, with emphasis on how intelligence will support our Force Projection Army in the Information Age. The basic requirements which the vision supports are: Battle Command, Extended Battlespace Dominance (understanding the information battlefield, C2 Exploit, C2 Attack, and C2 Protect), Force Projection, and Operational Flexibility.

Key to Battle Command and Battlespace Dominance is information presentation to the commander in the form of visual displays. Intel XXI's three primary objectives are to provide to the commander a virtual, near-real time, continuous picture of the battlespace and intelligence support for targeting and Battle Damage Assessment. These objectives drive requirements for sensors, processors, and communications capabilities.

To accommodate the requirements of the future, IEW must use the Army's RDA concept and enabling strategies to guide its efforts. Today's technology is not sufficiently capable of fully satisfying Force XXI intelligence requirements. Efforts are underway to consolidate and accelerate several disparate programs in order to field key capabilities in the following technology areas: Displays, Computer Hardware, Software, Visualization Data Bases, Sensors, Automatic Target Recognition, and Networks.

The capabilities described in this plan are augmented by the National Foreign Intelligence Program: General Defense Intelligence, Consolidated Cryptologic, and Foreign Counterintelligence Programs.

4. Roadmaps for IEW Systems

Table III-F-2 presents a summary of IEW demonstrations, ACTDs, ATDs, and S/SU/ACs as found in the IEW roadmaps. Systems/System Upgrades are the first step in fulfilling the IEW strategy. These will evolve from current systems through the use of Product Improvement Programs (PIP) and Preplanned Product Improvements (P3I). Technology demonstrations and ATDs will be utilized to facilitate the transition of technology through block improvements to existing or new systems. The challenge is to field a family of IEW systems which use a common module open architecture, thus improving flexibility, reducing the logistics burden, and minimizing development costs.

For the far term, future systems planning is focused on the integration of IEW systems with command, control, and communication systems into one C3IEW "system-of-systems" which will carry out the presentation, management, collection, processing, dissemination, transport, and denial of battlespace information.

The following sections contain roadmaps which lay out the required program efforts in information collection (Figures III-F-1a and III-F-1b), information processing (Figure III-F-1c), and information denial (Figure III-F-1d). Each section contains descriptions of associated

Table III-F-1. IEW System Capabilities

S/SU/AC FUNCTION	Early Entry	Depth and Simultaneous Attack	Mounted Battlespace	Dismounted Battlespace	Battle Command	Combat Service Support	SYSTEM/SYSTEM UPGRADE CAPABILITIES	ADVANCED CONCEPT CAPABILITIES
	BATTLEFIELD DYNAMICS							
CLOSE RSTA							• ELINT, COMINT, EA radar multi-sensor package • Sensor to detect, track, classify, vehicle and personnel • UAV penetration and stand-in RSTA/EW modular payload	• Integrated system of sensors and collectors • Survivable - All weather - All echelons • Mobile • Flexible and adaptable • Multiplatform - Ground based - -Airborne • Multispectral and integration - Imagery assessment - Acoustic - Radar - Laser - COMINT - ELINT - HF-EHF • Accurate - Range - Location - Percent detected • Modular - Common platforms - Common hardware and software • On-board preprocessing
System								
• Ground-Based Common Sensor-H[1]		●	●	●				
• Ground-Based Common Sensor-L	○	○		○				
• Tactical UAV Intell Package		●	○	●				
System Upgrades								
• Advanced QUICKFIX	○	●	●	●				
Advanced Concepts								
• Integrated Intercept	○	●	○	●				
• Integrated Sensor	○	●		●				
DEEP RSTA (GROUND/AIRBORNE)							• Mobile Near Vertical Incident Signal HF/DF collection • Manned aircraft with multi-purpose RSTA sensor suite • Airborne SIGINT/IMINT/Radar/ELINT/ MASINT collection system for mid-range emitter mapping • UAV modular sensor (imagery, meterological, NBC) with cross-cueing/processing • UAV stationary target ID sensor classification	
System Upgrades								
• Enhanced TRACKWOLF		●		●				
Advanced Concepts								
• Integrated Intercept	○	●	○	●				
• Integrated Sensor	○	●		●				
PROCESSING AND FUSION							• Situation development target engagement • Intel-on-the-move, antenna upgrades • Automated weather decision aids	• Mapping Propagation • Single, multiple, and all sources processing • Intelligent information –Correlation and fusion --Expert systems --Decision aids --Artificial intelligence - Target identification - Target nominations - Situation analysis • Information dissemination - Multi-echelon - Close-loop target hand-off • Common modules - Hardware and software - Built-in training
System Upgrades								
• ASAS Upgrades		●	●	○	○			
• Integrated Meteorological System (IMETS)		●	○	○	●	○		
Advanced Concept								
• Distributed IEW Fusion		●	●	○	○			
ELECTRONIC ATTACK/ PROTECTION							• Stand-In/UAV • HF-UHF and Beyond (Threat Dependent) • Stand-off • Long Range Electronic Attack • Active/Passive Cooperative Target ID • Vehicular self-protection • Aircraft self-protection/SEAD • Laser warning • IR CM • High power MW, MMW - Aircraft protection • Jammer family - Communications, noncommunications - Multisignal - MultispectralAutonomous • Stand-off	• Penetration • Implanted • Expendable • Active/Passive Non-cooperative IFF • Protection against - Ground based - Airborne - Space based - Radar, IR, EO • On-Board C2 integration • Laser Beam Rider Warning/CM
System								
• Tactical UAV Intell Package		●	○	●				
• Ground-Based Common Sensor-H		●		●				
System Upgrades								
• Advanced QUICKFIX[1]	○	●		●				
• Suite of Integrated RF CM	○	●	●	●				
Advanced Concepts								
• Suite of Integrated IR CM	○	●	●	●				

● Provides significant capability   ○ Provides some capability   [1] Contains Com Jam capability

Table III-F-2. IEW Demonstration and System Summary

ATDs	TECHNOLOGY DEMONSTRATIONS
• Air/Land Enhanced Reconnaissance and Targeting (See Aviation) • Target Acquisition (see Mounted Forces) • Hunter Sensor Suite (see Close Combat Light) • Battlefield Combat Identification (BCID) • Multispectral Countermeasures (see Aviation) • Multifunction Staring Sensor Suite (see Mounted Forces) **ACTDs** • Joint Precision Strike Demonstration (JPSD) – Precision/Rapid Counter MRL ACTD • Rapid Force Projection Initiative (see CCL section) • Rapid Battlefield Visualization (For additional information, see Volume II, Annex B.)	**IEW Ground-Based Collection Demos** • Low Probability of Intercept Electronic Support (ES) • Impulse/Wideband ES • New Signals SIGINT DF Development • Advanced ES Receiver • High Frequency (HF) Antenna • Modern Communications Beamformer ES/EA • Machine Vision for Autonomous Unmanned Ground Vehicle (UAV) **IEW Airborne Collection Demos** • ORION • Aerial Scout Sensor Integration • Multi-Mission/Common Modular UAV Sensors • SAR Target Recognition and Location System (STARLOS) **Intelligence Processing and Fusion Demos** • Multiple Source Correlated Intelligence Fusion Demo • Owning the Weather **Information Denial Demos** • Advanced Digital Electronic Attack • New Threat EA • SAR Deception Techniques • C2 Attack and Protect
SYSTEMS/SYSTEM UPGRADES/ADVANCED CONCEPTS	
Systems • Ground-Based Common Sensor-Heavy • Ground-Based Common Sensor-Light (LW SIGINT Division) • Tactical UAV Intelligence Package ***System Upgrades*** • Advanced QUICKFIX (Aerial Common Sensor-Div) • ASAS Upgrades • Enhanced TRACKWOLF • Integrated Meteorological System (IMETS) • Suite of Integrated RF Countermeasures	***Advanced Concepts*** • Integrated Intercept System • Integrated Sensor System • Distributed IEW Fusion • Suite of Integrated IR Countermeasures

technology demonstrations which support IEW S/SU/ACs.

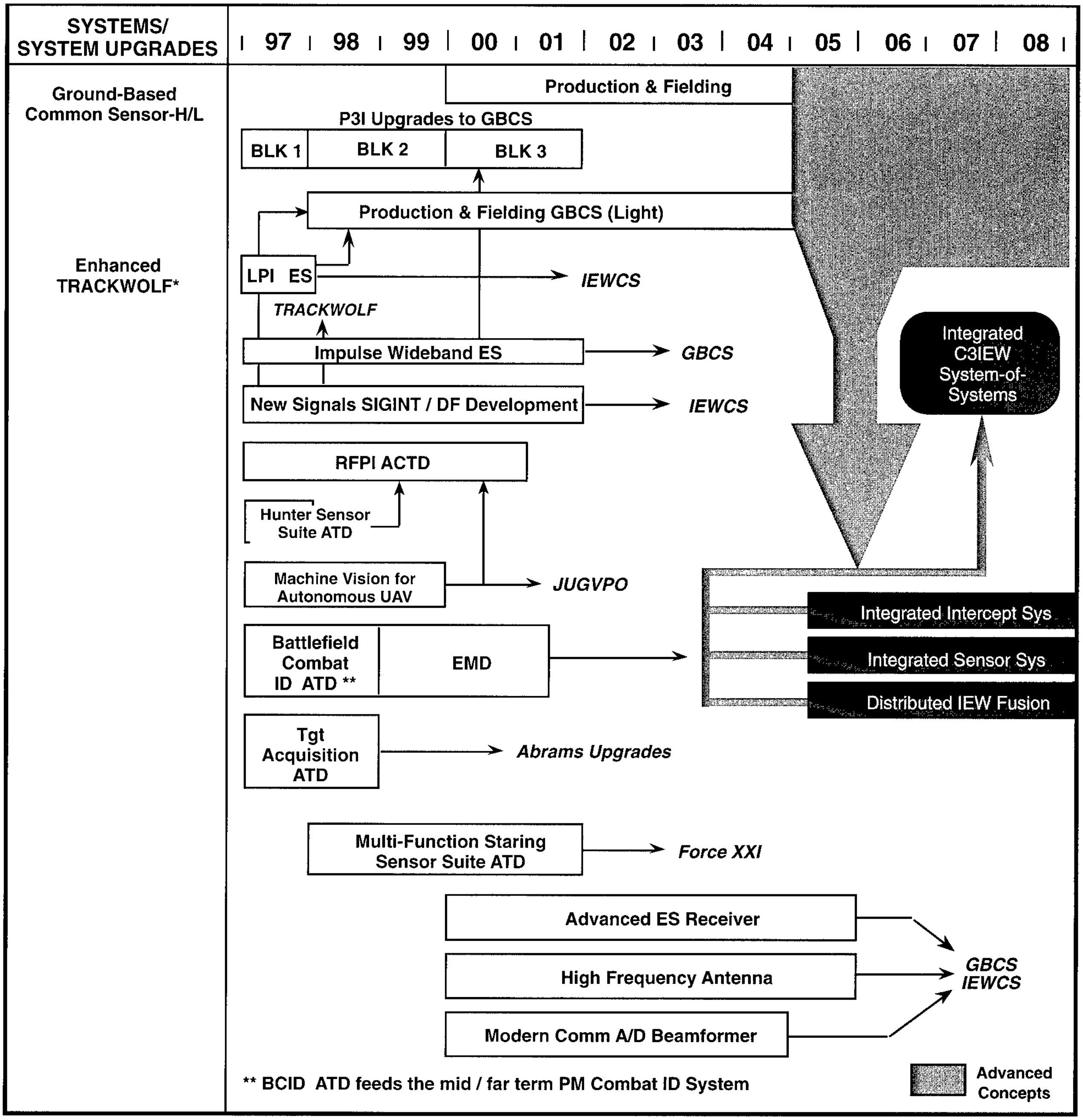
Most of the demonstrations directly support the systems that form the basis of the IEW Annex to the AMP. The remaining demonstrations represent initiatives that support a variety of IEW systems, or are technology programs supporting non-MI systems not specifically addressed in the IEW Annex to the AMP.

a. Technology Programs Leading to Information Collection for IEW Ground-Based Collection Systems

Ground-based collectors for IEW ground-based collection systems are targeted against multiple echelons. They embody modular, scalable, multi-sensor capabilities that combine electronic intelligence (ELINT), communications intelligence (COMINT), and electronic attack (EA). The mix of systems ranges from transportable to manpack. Each provides surveillance, targeting, and intelligence data to be correlated with data provided by other sensors. The roadmap for ground-based collection systems is shown in Figure III-F-1a.

Rapid Force Projection Initiative (RFPI) ACTD (95-00). The RFPI ACTD will demonstrate automated target transfer from forward sensors to standoff killer weapon systems with the capability to engage high value targets beyond traditional direct fire ranges. Details of the RFPI ACTD can be found in *Close Combat Light*, Section H.

Figure III-F-1a. Roadmap for IEW (Information Collection) Modernization—Ground-Based



* System Upgrades

Hunter Sensor Suite ATD (94-97). This ATD will demonstrate the feasibility of a lightweight, deployable, and survivable hunter vehicle platform with an advanced, low observable, long-range hunter sensor system with aided target recognition and enhanced target handover. See section III-H, *Close Combat Light*, for more detailed information. The Hunter Sensor Suite ATD is an integral part of the RFPI ACTD.

Target Acquisition ATD (95-98). This ATD will develop, integrate, and demonstrate advanced target acquisition and identification sensors, and thermal driving technologies for future "heavy" force vehicles. See section III-G, *Mounted Forces*, for more detailed information. This ATD is a key element for the development of advanced target acquisition systems for the Advanced Tank Technology Program, Future Scout and Cavalry System (FSCS), Armored Gun System (AGS), and Future Tank.

Machine Vision for Autonomous Unmanned Ground Vehicle (UGV) Technology Demonstration (96-99). Through this technology demonstration an autonomous navigation capability will be developed and demonstrated on a UGV that allows operation on or off roads, that can detect and circumnavigate obstacles, and that can autonomously re-plan its route if it becomes impassable for any reason. Landmark identification techniques, required for precision targeting applications, will also be demonstrated. This machine vision system makes use of artificial intelligence techniques (which includes neural network and fuzzy logic) and image processing to provide vehicle steering and velocity control command. In addition, the system will integrate GPS technology, imaging sensors, and advanced route/mission planning technology. The enhancement of machine vision for autonomous vehicles will reduce soldier risk and soldier burden. The application of this technology will transition on an individual basis. **Supports:** Joint UGV Project Office, Rapid Force Projection Initiative ACTD, Early Entry Lethality and Survivability, Dismounted Battle Space, Combat Service Support, and Depth and Simultaneous Attack Battle Labs.

Low Probability of Intercept (LPI) Electronic Support (ES) (94-97). This effort will demonstrate the capability to intercept and geolocate current and emerging threat noncommunications emitters which use LPI technology. The objective is to develop a family of mini, modular, fully-automatic technologies for insertion into existing systems. The technology which is being investigated includes the development of processors using Very High Speed Integrated Circuit (VHSIC) technology to perform onboard identification of noncommunication emitters and to obtain weight, size, and power reductions as well as increased processing speeds. Receiver developments will focus on increasing system sensitivity for operations in a dense signal environment. Advancements in antenna designs are being pursued for the development of a lightweight, wideband, circularly disposed conformal antenna to replace the high profile spinning dish antennas currently in use today. **Supports:** UAV equipment packages, Ground-Based Common Sensor (GBCS), IEW Common Sensor (IEWCS), Enhanced TRACKWOLF, and Advanced QUICKFIX.

Impulse/Wideband Electronic Support (ES) (97-01). This demonstration will focus on developing advanced techniques to detect, characterize, and geolocate impulse radars in the presence of conventional radars and communication signals. Impulse radars represent a significant advance in the state of the art for battlefield radars. Since they were developed to counter detection, location, and destruction, current countermeasures are ineffective against them. This work will involve a coordinated effort which includes tri-Service and international participation, as well as the use of the SBIR program. The objective of these programs is to develop technology for insertion into current and future ES systems to counter the emerging impulse radar threat. **Supports:** GBCS.

Battlefield Combat Identification (BCID) ATD (93-98). The goal of the BCID ATD is to solve the combat identification (ID) problem experienced in Operation Desert Storm. It provides the Army's technology options for the Joint Combat ID ACTD. This ATD builds upon the Battlefield Combat Identification System (BCIS) near-term solution, presently being developed for vehicle platforms (a millimeter-wave, question-and-answer type target ID system), and validates the architecture for a comprehensive air-to-ground and ground-to-ground BCIS-compatible system that includes the dismounted soldier. Previous experiments and demonstrations assessed requirements and concepts for the dismounted soldier and provided the technical foundation for the Joint Combat ID ACTD and integrated air-to-ground and ground-to-ground applications, including situational awareness through the gunner's sight. FY97 efforts include constructive modeling and virtual simulation of air-to-ground combat ID systems, initial simulation of dismounted soldier CI systems, initial field experiments with advanced technologies for enhanced target ID and support of Force XXI. Future efforts will include demonstration of a lightweight combat ID capability for dismounted soldiers, integration into the Land Warrior equipment suite, analysis and development of target ID concepts for soldier-to-vehicle, vehicle-to-soldier, and helicopter-to-soldier applications and extension of the situational awareness through-the-site effort to include an enhanced version of BCIS, the digital Appliqué, and other acquisition and target ID systems. **Supports:** Armored Vehicles, the Integrated C3IEW System-of-Systems, and Land Warrior.

New Signals SIGINT/DF Development (94-01). This project will develop the technology necessary to provide non-cooperative intercept and geolocation of modern communication signals. Successful developments will be transitional into the tactical flagship systems as they mature. **Supports:** Enhanced TRACKWOLF, IEWCS.

Advanced Electronic Support (ES) Receiver (00-05). This program will demonstrate a digital reconfigurable receiver to accommodate a variety of missions. This digital channelized receiver is intended to upgrade the IEWCS front end to intercept very wide band signals in a single channel mode, as well as to spatially resolve narrow band signals in a multichannel mode. This ensures exploitation of modern communication signals and efficient allocation of system resources. **Supports:** IEWCS, GBCS.

High Frequency (HF) Antenna (00-05). This program will demonstrate high frequency antenna and antenna coupler components based on high temperature super conductive technology to reduce size and weight on IEWCS platforms and allow tactical HF Electronic Warfare. **Supports:** IEWCS, GBCS.

Modern Communications Analog/Digital Beamformer Electronic Support/Electronic Attack (ES/EA) (00-04). The ability to spatially resolve targets using beamforming developments will increase the stand-off ranges in which communications collection can occur or provide greater system sensitivity for signals at lower signal-to-noise ratios at current stand-off ranges. This program will demonstrate the effective use of this technology to address the frequency re-use or co-channel interference problem in modern communications collection and identification to support electronic attack issues. **Supports:** IEWCS, GBCS.

Multifunction Staring Sensor Suite (MFS3) (98-01). This ATD will focus on a modular, reconfigurable MFS3 that integrates multiple advanced sensor components including staring infrared arrays, multifunction laser, and acoustic arrays. For further details, see *Mounted Forces*, Section G. **Supports:** Future Scout and Cavalry System (FSCS), Bradley Stinger Fighting Vehicle-Enhanced (Linebacker), Force XXI.

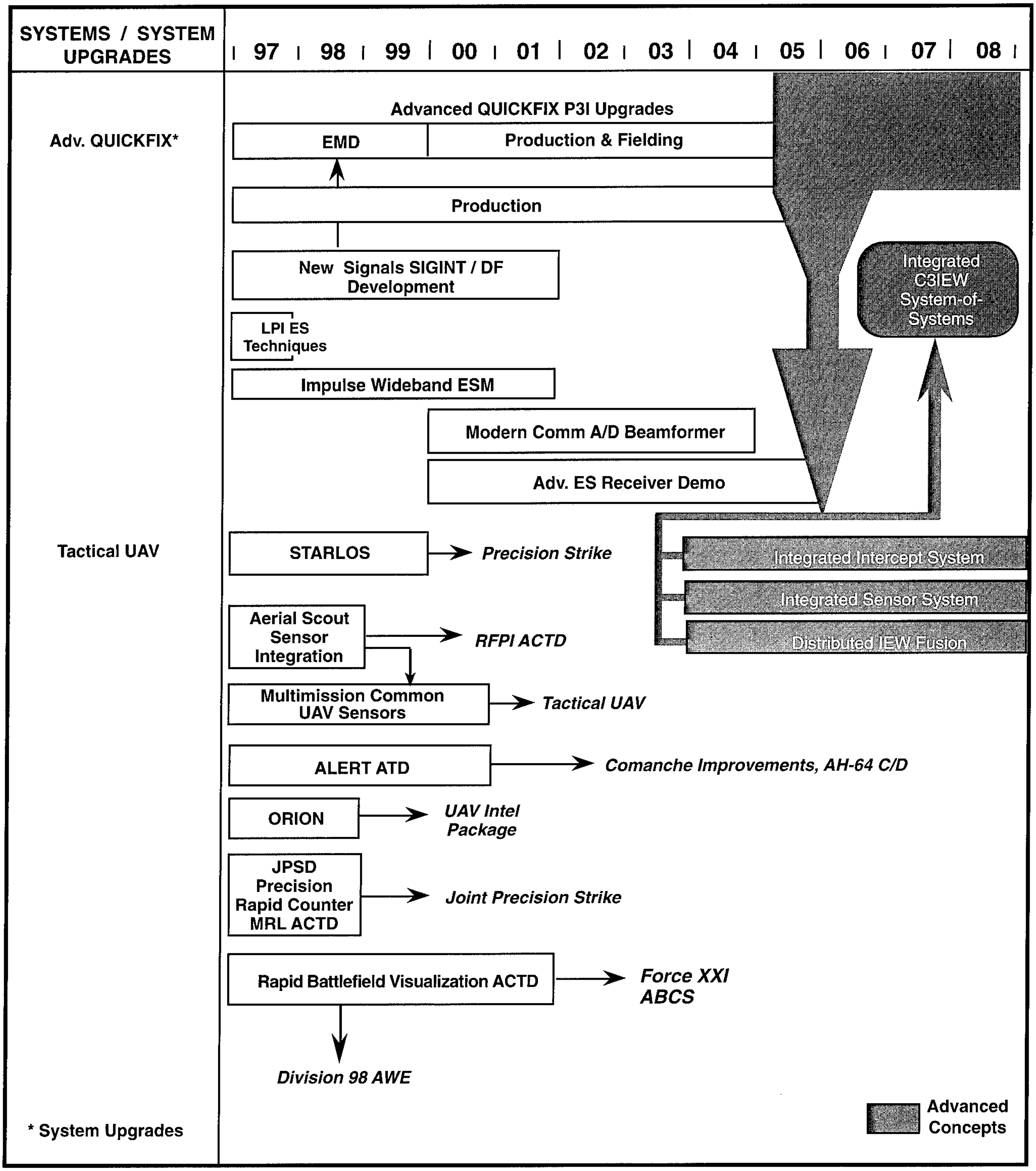
b. Technology Programs Leading to Information Collection Modernization for IEW Airborne Collection Systems

The roadmap for airborne information collection shows a mix of manned and unmanned platforms. The manned aircraft will undergo preplanned product improvements which will add required capabilities on an incremental basis. Unmanned airborne vehicles will carry a variety of IEW sensor packages. The roadmap is shown in Figure III-F-1b.

Air/Land Enhanced Reconnaissance and Targeting (ALERT) ATD (97-00). The purpose of this ATD is to demonstrate automatic target acquisition and enhanced target identification, to cover large search areas with high targeting accuracy while at low depression angles and high platform motion. See *Aviation*, Section D, for further details. **Supports:** Comanche Improvements, AH-64 C/D Apache.

JPSD Precision/Rapid Counter MRL ACTD (95-98). This ACTD will demonstrate a significantly enhanced capability for U.S. Forces Korea (USFK) to neutralize the newly deployed North Korean 240mm multiple rocket launcher (MRL) system. Because of the brief time in which this target is expected to be exposed and vulnerable to counterfire, near continuous surveillance and near instantaneous target acquisition will be required. The terrain problems require that a sensor be overhead and that Division-level access be available. A second generation infrared linescanner called the Reconnaissance Infrared Surveillance and Target Acquisition (RISTA II for second generation) was developed with an Aided Target Recognizer And Processor (AiTRAP). This system provides high resolution, wide area coverage, and automatic target chip presentation to a targeteer. The system was proven in FY96 at a demonstration at Fort AP Hill. Following review by SARDA and OSD(AT), the system will be transitioned to the Multi-Sensor Test Bed and Sherpa aircraft assigned to PM-TESAR for further demonstration and operational evaluation. The sensor leave-behind for the CMRL problem is an Aided Target Recognizer for application to TESAR. The AiTR will cue the targeteer to 240 MRL targets. A preliminary demonstration of this capability was shown in FY96 at Fort AP Hill. The first leave-behind will be a Challenger-based system for CONUS Predator systems in FY97 and the second leave-behind will be a COTS processor in the Predator GCS for OCONUS deployment. **Supports:** Joint Precision Strike.

Figure III-F-1b. Roadmap for IEW (Information Collection) Modernization—Airborne



Rapid Battlefield Visualization (RBV) ACTD (97-01). This ACTD will demonstrate capabilities to rapidly collect source data and generate high resolution digital terrain databases to support crisis response and force projection operations within the timelines required by the joint force commander. It will demonstrate capabilities for the commander to integrate these terrain data bases with current situation data, and manipulate and display the integrated data bases to determine how to achieve objectives and visualize the desired end state. The RBV ACTD will leave behind with the XVIII Airborne Corps the computer workstations and applications software to (1) generate high resolution terrain data bases; and (2) analyze courses of action using mission planning and embedded wargaming software and conduct mission rehearsals. This ACTD will leverage the Battlefield Awareness and Data Dissemination (BADD) ACTD for data dissemination and tactical communications; the Battlespace Command and Control (BC2) ATD for applications software and communications architectures; and enhanced terrain representation programs conducted by the Terrain Modeling Project Office of the Defense Mapping Agency. **Supports:** Force XXI, Army Battle Command System (ABCS), Division '98 AWE, and Intel XXI.

Aerial Scout Sensor Integration Technology Demonstration (95-98). This program will demonstrate UAV-mounted imaging sensors and ground-based image exploitation workstation capable of high resolution, wide-area coverage for battlefield reconnaissance, surveillance, non-line-of-sight targeting, and battle damage assessment. See section III-H, *Close Combat Light*, for more detailed information. **Supports:** Rapid Force Projection Initiative ACTD.

Multimission/Common Modular UAV Sensors (97-00). This technology demonstration will provide a low cost, lightweight, EO/IR integrated MTI Radar/SAR payload for integration on future tactical UAVs. The radar payload will build upon successes in the current low cost radar development program and will likely utilize MMIC. The FLIR will take advantage of high quantum efficiency, 3–5 micron staring arrays. These sensor payloads will provide enhanced reconnaissance, surveillance, battle damage assessment, and targeting for non-line-of-sight weapons. Demonstrations will focus on multiple mission flexibility in support of early entry and deep attack forces. **Supports:** Tactical UAV.

LPI ES and Impulse Wideband ES. See description in Ground-Based Collection Systems section (above).

ORION (95-98). This program will demonstrate the operational effectiveness of a wide bandwidth SIGINT Electronic Support (ES) package on a surrogate UAV platform operating in conjunction with a ground-based IEW Common Sensor which receives the UAV ES detected signals and performs the intercept/processing task to locate high value C2 targets, thus enhancing the capabilities of the IEW Common Sensor by allowing deeper penetration of the enemy's communications space to detect even low signal levels from directional systems such as multichannel. The system will also allow the intercept of modern low power communications. Collection of these signals is difficult due to low radiated power. ORION provides needed access to these signals. There are also plans to include Electronic Attack into the package to provide a unique capability to attack deep targets and assist in the execution of Information Warfare missions against critical deep targets. **Supports:** UAV Intell Package.

Advanced ES Receiver Demo and Modern Communications Beamformer ES/EA Demo (00-05). See description in Ground-Based Collection System section (above).

Synthetic Aperture Radar (SAR) Target Recognition and Location System (STARLOS) (94-99). This program will develop real-time Aided/Automatic Target Recognition (ATR) capabilities and demonstrate their functionality in a number of different platforms using Synthetic Aperture Radar (SAR) as sensor. The ATR capabilities will be demonstrated in the ground station for the aerial platforms and will concentrate on the detection, classification, recognition, and identification of high value/payoff targets. The program will provide location of time critical targets in day/night and most weather conditions using wide area coverage rates. Since multiple platforms will be addressed, the ATR algorithms will be implemented using scalable common ATR hardware which is anticipated to be completely COTS by FY97. In addition, the scalable hardware will be used to execute algorithms for other sensors including 2nd Gen FLIR/LS, thus allowing more platforms (both intelligence and combat weapon) to be considered for potential ATR insertion using the principles of Horizontal Technology Integration (HTI). **Supports:** Precision Strike, Medium Altitude Endurance UAV.

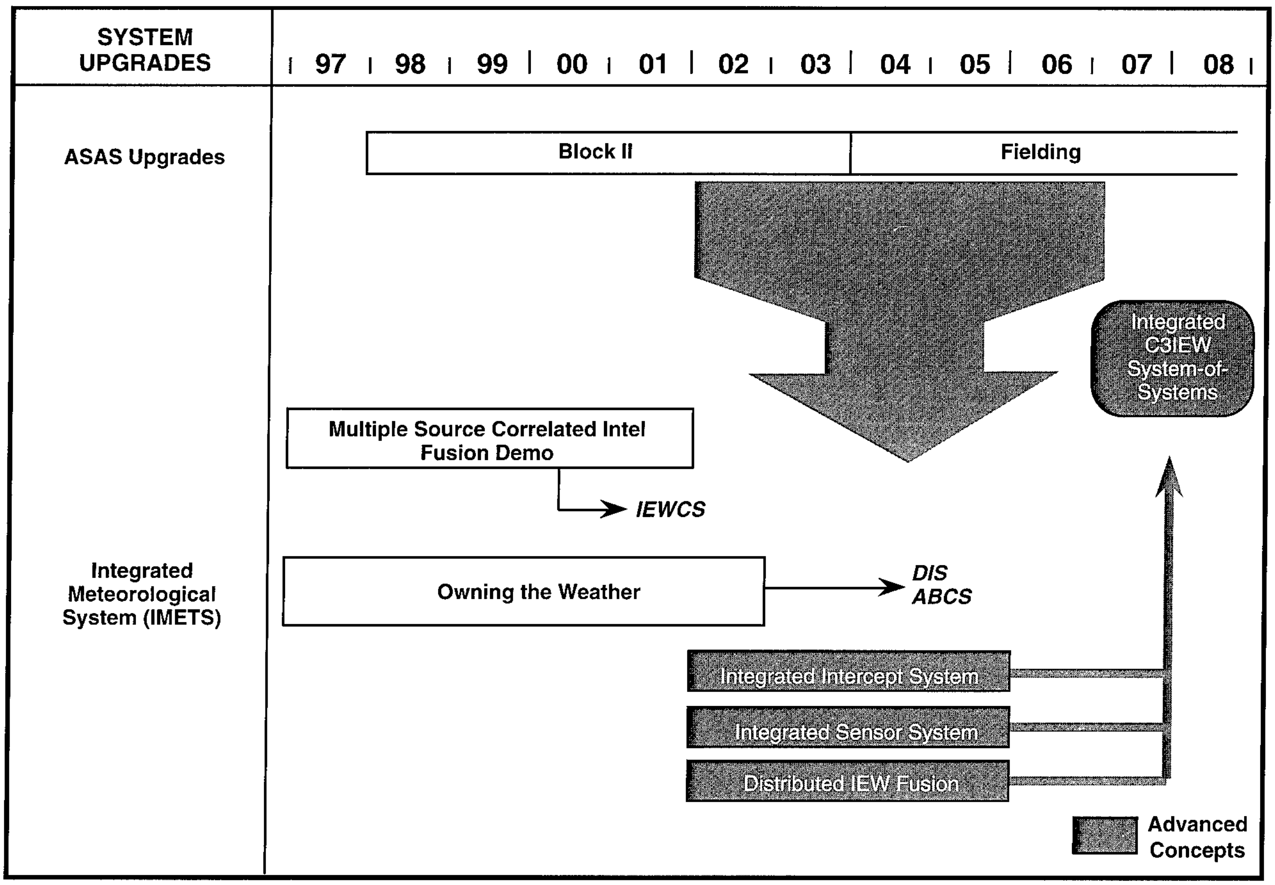
c. Technology Programs Leading to Intelligence Processing and Fusion Modernization

The objective of intelligence fusion and processing modernization is the development and fielding of common hardware and software for intelligence analysis centers. The goal is to shorten timelines for supplying intelligence to the commander and to provide real time target information to weapon systems. The roadmap is shown in Figure III-F-1c.

Multiple Source Correlated Intelligence Fusion Demonstration (96-01). This effort will demonstrate a fully integrated tactical intelligence data fusion module at Corps and Division levels. The module will be stimulated with diverse inputs and perform various fusing functions to provide the commander with a comprehensive visualization of the battlefield using advanced, multi-media display techniques to provide complete status of the situation in an easily viewed and understandable format (status at a glance). Inputs to the module will be from the entire suite of battlefield sensors and both tactical and strategic intelligence sources. Sensors will be queued, and remote resources queried, to synchronize the fusion effort with the supported tactical operation. Data will be correlated using advanced fusion techniques such as automated terrain reasoning for location and movement analysis and amalgamated into intelligence products. This module will support functions from the initial Intelligence Preparation of the Battlefield to final battle damage assessments and will also assist in fratricide prevention. **Supports:** ASAS and IEWCS.

Owning the Weather (96-02). This program consists of three interrelated technology demonstrations that will transition directly from 6.2 into the Integrated Meteorological System (IMETS) block upgrades, artillery fire control and meteorological systems, Army Battle Command System (ABCS), Battlefield Automated

Figure III-F-1c. Roadmap for IEW (Information Processing) Modernization—Fusion

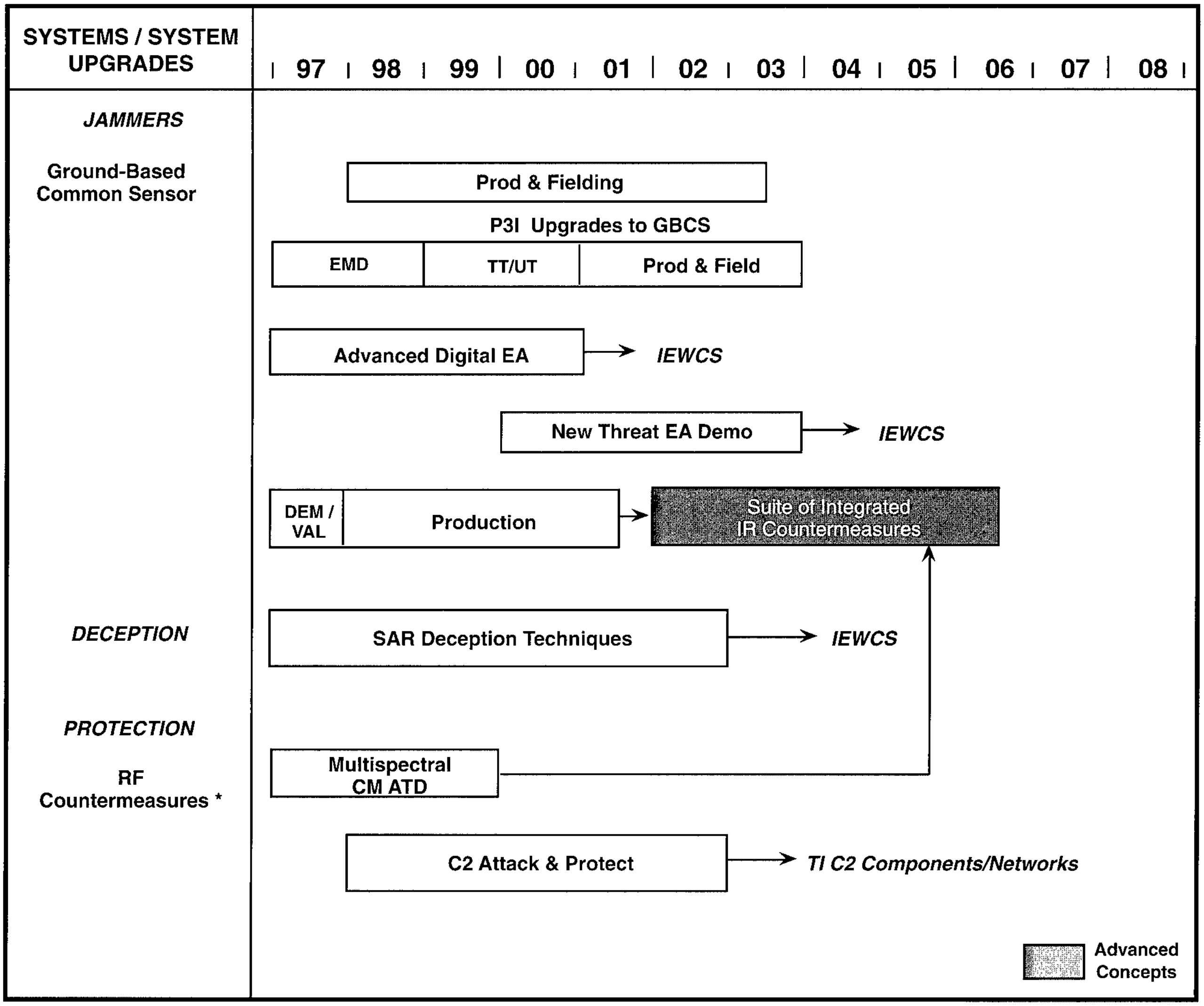


Systems (BAS), and the Modeling and Simulation (M&S) community. The first, Target Area Meteorology, is aimed at developing Computer Assisted Artillery Meteorology software and battlescale weather forecasting techniques. It will receive input from mobile atmospheric profilers and weather satellites to improve precision strike and artillery firing accuracy through better knowledge and application of battlefield and target area meteorological conditions. The second, Automated Weather Decision Aids, will enable commanders to apply this improved knowledge of battlefield weather to compare weather-based advantages/disadvantages of friendly and threat systems using automated decision aid client applications on ABCS BASs served by the IMETS through a Distributed Computing Environment. The third, Owning the Weather, extends the target area meteorology and decision aid technology to the M&S environment so that realistic operational battlescale forecast weather and predicted impacts on systems and operations are also useable in mission rehearsal, training, and combat simulations. **Supports:** IMETS, ABCS, and Distributed Interactive Simulation.

d. Technology Programs Leading to Denial Systems Modernization

Denial systems are categorized into three main areas: jamming systems, deception systems, and self-protection systems. The objective of these systems is to deny the enemy vital information and to deceive and disrupt his command and control and weapon systems. The roadmap is shown in Figure III-F-1d.

Figure III-F-1d. Roadmap for IEW (Information Denial) Modernization



* System Upgrades

Multispectral Countermeasures ATD (97-99). The purpose of the Multispectral Countermeasures ATD is to develop prototype hardware for advanced technology, countermeasures to protect Army helicopters from imaging surface-to-air missiles. See *Aviation* (Section III-D) for more detailed information. **Supports:** Suite of Integrated IR Countermeasures, RF Countermeasures.

C2 Attack and Protect Technology Demonstration (98-02). This TD will demonstrate the ability to launch effective Command and Control (C2) Attack against Integrated Battlefield Area Communications Systems (IBACS) (threat information systems). It will also demonstrate the ability to protect the Army's Tactical information systems, components, and data from modern network attacks. The demonstration will leverage existing technology, exploit modeling and simulation methods for concept exploration and definition, and use C2 attack capabilities against Tactical Internet (TI) information systems and components. For each C2 attack method a countercapability (C2 Protect) will be incorporated. The demo will provide the ability to selectively control an adversary's use of information, information-based processes, and information systems through the application of offensive capabilities that deny, disrupt, or degrade operations or capabilities. **Supports:** RF Countermeasures, TI C2 Components and Networks.

Advanced Digital Electronic Attack (EA) (95-00). This demonstration will establish the effectiveness of exploitation and jamming techniques based on vulnerabilities of various format modern analog and digital communications systems. A prototype system for detecting and collecting analog and digital signals will be fabricated to allow for demonstration of proof of concept countermeasures techniques. **Supports:** IEWCS, GBCS.

New Threat Electronic Attack (EA) (00-03). This program will demonstrate the ability to intercept, locate, and disrupt emerging high priority threat systems utilizing advanced communications technologies. This program will also investigate the advanced digital signal processing, encryption, and complex modulation techniques being incorporated into many of the commercial systems proliferating throughout the world. **Supports:** IEWCS, GBCS.

Synthetic Aperture Radar (SAR) Deception Techniques (97-02). This exploratory development project will yield components to counter, through deception techniques, the SAR threat. These components include hardware, software, and associated techniques, as well as ancillary equipment. The requirements to deceive and jam air defense and surveillance radar will continue to increase as new threat radars are developed that use bistatic and other advanced techniques to avoid destruction and to counter low observables. **Supports:** IEWCS.

5. Relationship to Modernization Plan Annexes

Figure III-F-2 shows the correlation between IEW S/SU/ACs and other Army Modernization Plan Annexes. Note that IEW sensors provide a significant capability in the Modernization process of other mission areas.

The long-term goal is for Army C3IEW functions to evolve into an integrated Battlespace Information System (BIS-21) which provides for the information collection, management, transport, and denial functions required in the 21st century. This BIS-21 concept is synchronized with the DoD "C4I for the Warrior" concept, which promotes the ability of a warfighter to globally "plug in" and obtain required battlespace information at any time.

Figure III-F-2. Correlation Between Intelligence and Electronic Warfare S/SU/ACs and Other Army Modernization Plan Annexes

INTELLIGENCE AND ELECTRONIC WARFARE SYSTEMS/SYSTEM UPGRADES/ADVANCED CONCEPTS		MODERNIZATION PLAN ANNEXES: C4	Aviation	Fire Support	Air Defense Artillery	Close Combat Light	Mounted Forces	Engineer and Mine Warfare	Space
SYSTEMS	Ground-Based Common Sensor H/L		●	●	○	●	●		
	Tactical UAV Intel Package	○	○	●		●	●		
SYSTEM UPGRADES	Enhanced TRACKWOLF	○	○	○	○				
	Advanced QUICKFIX	○	○		●				
	ASAS Upgrades	○		○	○				○
	Suite of Integrated RF Countermeasures		●	○			○		
	Integrated Meteorological System (IMETS)	○		○		○	○		
ADVANCED CONCEPTS	Integrated Intercept System	○		○	○				
	Integrated Sensor System	○		○	○		○	○	
	Distributed IEW Fusion	○		○	○	○	○		○
	Suite of Integrated IR Countermeasures		○				○		

● Provides significant capability

○ Provides some capability

G. Mounted Forces

1. Introduction

The greatest Science and Technology (S&T) challenge in the Mounted Forces mission is to make our most capable mounted forces lighter, more lethal, and more deployable to better react to regional conflicts in the post-Cold War era, while improving their mobility, C4I capability, and survivability.

Over the last few years, changes in the geopolitical climate have shifted the threat away from our traditional Cold War adversaries. Today any country has rapid access to state-of-the-art weapon systems (e.g., precision guided munitions) and vehicles for their warfighting arsenal. In order to counter foreign capabilities, we will continue to rely on the systems purchased mostly in the 1980s and plan for upgrades to those vehicle fleets, take advantage of commercial technology advances (e.g., computers, communications, electronics), and improve the ability to sustain the fleet at lower cost. These Mounted Force S&T opportunities are focused through the Advanced Vehicle Technologies (AVT) integration program.

The need for rapid deployment of the Mounted Force to any battlefield in the world emerged as a lesson learned from Operation Desert Shield. New requirements for the force has drastically changed combat vehicle design considerations. The creation of lighter, more mobile, more supportable vehicles is now an integral part of the S&T investment strategy. But simply increasing the deployability at the expense of the capabilities of our combat systems is not acceptable. We must increase deployability while simultaneously advancing our superiority in lethality, C4I, survivability, and battlefield mobility. This is where our technology base is critical in forming a viable basis for these new, more capable, smaller, lighter fighting vehicles.

Mounted Forces require expanded capabilities to acquire and kill the array of threat targets in all weather, on the move, day/night, in cluttered environments, and at long ranges with increased probability of destruction out to the extent of the commander's battlespace. S&T programs must focus on warfighter needs for future systems and/or system upgrades. Investments are being made to apply technology horizontally across multiple combat and tactical systems.

2. Relationship to Operational Capabilities

Mounted Forces Systems Upgrades/Advanced Concepts (SU/ACs) address the progress of the Army's desired operational capabilities, as they relate to the Battlefield Dynamics shown in Table III-G-1. A direct correlation exists between the SU/ACs listed and the relevant TRADOC Battlefield Dynamics.

3. Modernization Strategy

Dominate the Maneuver Battle is one of the Army's modernization objectives. The Mounted Forces section of Annex B, Combat Maneuver, in the 1996 Army Modernization Plan Annex supports this objective by providing an assessment of the Mounted Forces' strengths and weaknesses. The Annex also outlines a modernization program to correct deficiencies and exploit strengths. It calls for the following major improvements to continue our modernization program: increase target acquisition, digitize the battlefield, increase lethality, increase survivability, and improve force structure.

The AVT umbrella program addresses the needs identified in the Annex for a lighter, more deployable "Heavy" force that retains high levels of lethality and survivability. Many of the technologies and components within this section are candidates for product improvements to fielded systems, such as the M1A2 Abrams Tank.

Under the AVT programs, there are six Advanced Technology Demonstrations (ATDs) which are designed for integration into future vehicle concepts but also provide potential for upgrading existing vehicles. Collectively, they seek ways to reduce the size and weight of combat vehicle structure and subsystems by: reducing the requirement for conventional armor through countermeasures and active protection; reducing crew size through an integrated/automated crew station; improving the lethality of cannons and ammunition; and demonstrating lighter, more survivable vehicle

Table III-G-1. Mounted Forces Systems Capabilities

S/SU/AC FUNCTION	Early Entry	Depth and Simultaneous Attack	Mounted Battlespace	Dismounted Battlespace	Battle Command	Combat Service Support	SYSTEM/SYSTEM UPGRADE CAPABILITIES	ADVANCED CONCEPT CAPABILITIES
LETHALITY							• Increased target acquisition – Extended range – Integrated multispectral sensors – Positive hostile ID – All weather • Improved munitions – Top attack – Defeat advanced armors	• Advanced fire control – Extended range – Advanced TA – Positive hostile ID • Advanced Armament – Electrothermal gun – Electromagnetic gun – Liquid propellant – High power switches/transformers – Adv kinetic energy missiles and guided penetrators – Adv kinetic energy penetrator
System Upgrades								
M1A2 Abrams SEP			●	●	●			
M1A2 Abrams SEP+			●	●	●			
M2A3 Bradley			●	●	●			
Advanced Concepts								
Future Combat System (FCS)	○		●	●	●			
Future Infantry Fighting Vehicle (FIFV)	○		●	●	●			
Future Scout & Cavalry System (FSCS)	●	●	●	●	●			
SURVIVABILITY AND PROTECTION							• Integrated threat warning and countermeasures – Passive/active sensor mix for low spectral emissions – Automated response – Microprocessing – Fratricide avoidance	• Passive protection – Improved signature management – Increased ballistic protection • Active protection – Threat sensors and counter-measures • Composite structures • Reduced vehicle weight
System Upgrades								
M1A2 Abrams SEP			●	●	●			
M1A2 Abrams SEP+			●	●	●			
M2A3 Bradley			●	●	●			
Advanced Concepts								
Future Combat System (FCS)	○		●	●	●			
Future Infantry Fighting Vehicle (FIFV)	○		●	●	●			
Future Scout & Cavalry System (FSCS)	●	●	●	●	●			
MOBILITY AND ELECTRONICS							• Lighter forces – Improved force agility – Reduced fuel consumption • Reduced logistics • More transportable • Supports digital battlefield • Advanced crew station: – Improved vehicle control – Optimal soldier/machine interface – Reduction of crew workload – Advanced display technologies	• Lighter forces – Highly mobile – Advanced materials – Advanced propulsion – Advanced track – Electric drive – Active suspension • Integrated munitions/fuel/cargo transfer
System Upgrades								
M1A2 Abrams SEP			●	●	●			
M1A2 Abrams SEP+			●	●	●			
M2A3 Bradley			●	●	●			
Advanced Concepts								
Future Combat System (FCS)	○		●	●	●			
Future Infantry Fighting Vehicle (FIFV)	○		●	●	●			
Future Scout & Cavalry System (FSCS)	●	●	●	●	●			

The six ratings columns (Early Entry through Combat Service Support) are grouped under BATTLEFIELD DYNAMICS.

● Provides significant capability ○ Provides some capability

structures using composites with enhanced target acquisition and improved C2 through shared situational awareness.

The AVT programs are applicable to all ground vehicles but emphasize improvements in capabilities of light and heavy systems. Payoffs should include increased lethality; improved survivability through advanced armors, hit avoidance, and signature management, including inherent signature reductions; reductions in the number of ships required to deploy and sustain a heavy force; greater flexibility in the use of ground, sealift, and airlift assets; and greater tactical mobility and agility. The ATDs that support AVT are:

- Composite Armored Vehicle (CAV)
- Hit Avoidance
- Target Acquisition
- Direct Fire Lethality
- Battlespace Command and Control
- Future Scout and Cavalry System

AVT will provide a basis to modernize our existing fleet while providing a new strategically mobile, tailorable, and modular combat force able to defeat any threat anywhere in the world.

During FY96, five Integrated Concept Teams (ICTs) were formed to address solutions to user-defined requirements. These ICTs, along with their primary focus, are as follows:

- *Abrams ICT (current fleet modernization).* S&T activities will target technology transfer to M1A2 Abrams upgrades. The insertion of required technology will be facilitated by ongoing electronic upgrades.
- *Future Scout and Cavalry System (FSCS) ICT.* This ICT developed the program with a goal of fielding a new FSCS by FY2006. Specific attention is being given to stealth, a wide array of sensor capability, connectivity to the digitized battlefield, and survivability.
- *Future Combat System (FCS) ICT.* The FCS ICT devised a program to develop and field a "leap ahead" combat program to be fielded between FY2015 and FY2020.
- *Suite of Survivability Enhancements System (SSES) ICT.* The SSES ICT will coordinate the development of a suite of survivability enhancements for ground combat vehicles. This technology will protect the mounted force from known enemy threats.
- *Force XXI Battle Command Brigade and Below (FBCB2).* The FBCB2 ICT will conduct a concept review of C2 functions and will define required operational capabilities within Armor Center proponency for CAC2 at brigade and below.

4. Roadmap for Mounted Forces Modernization

Table III-G-2 presents a summary of demonstrations and technologies. The road map in Figure III-G-1 portrays the progression of the Mounted Forces program to include Technology Demonstrations (TDs), ATDs, and SU/ACs.

a. AVT Lethality Demonstration

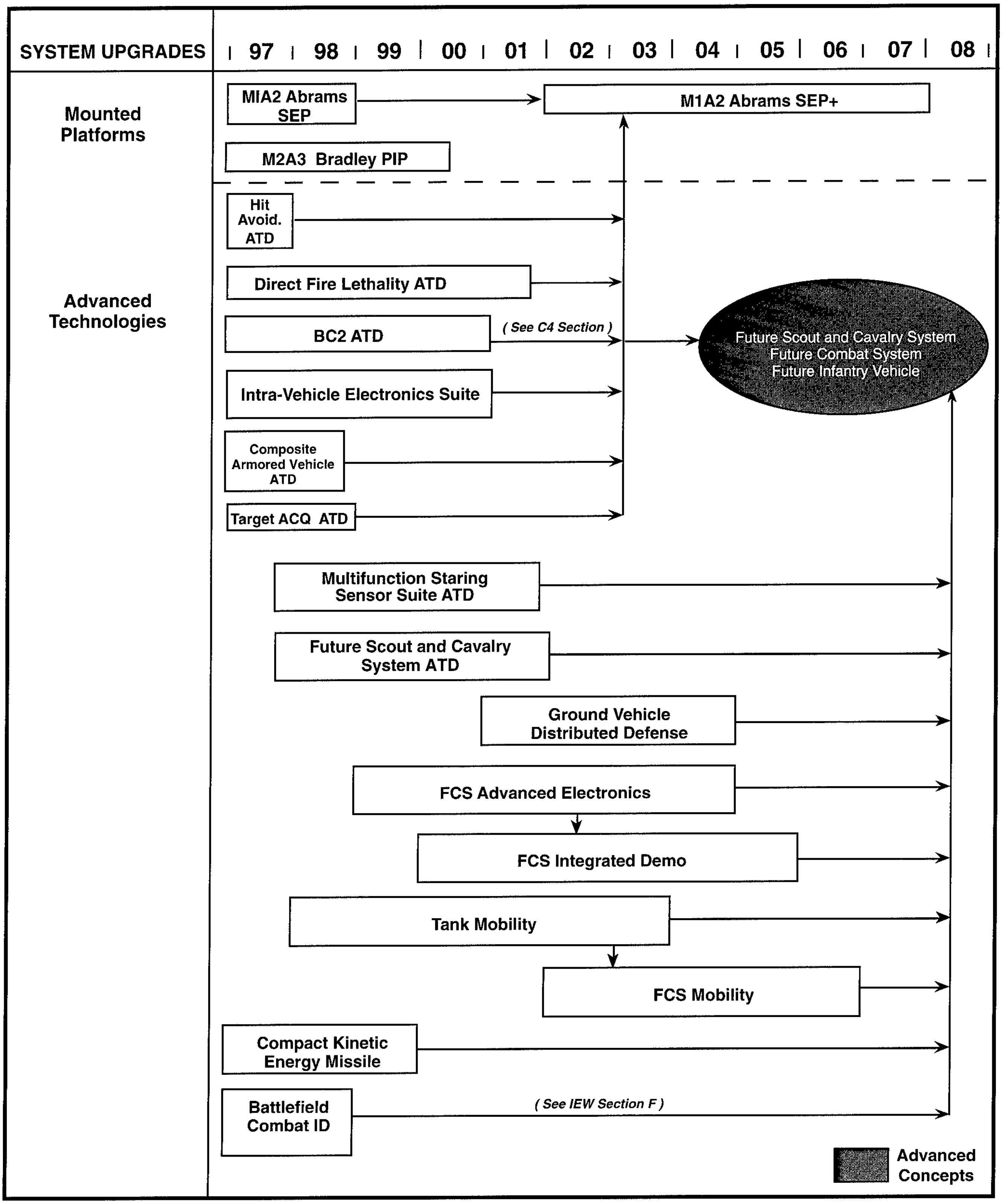
Direct Fire Lethality ATD (96-01). This ATD will demonstrate promising technologies to enhance the hit and kill capabilities of armored vehicles. Technologies must be explored that provide a quantum leap in performance with little or no weight/volume burden on the vehicle. Emphasis will be placed on defeat of advanced appliqué armors utilizing precursors for Kinetic Energy (KE) penetrators. To provide improved weapon stabilization, technologies such as Distributed Direct (Gearless) Drives and Smart Barrel Actuators will be incorporated into the turret and main gun to increase the probability of a hit and kill. **Supports:** M1A2 Abrams System Enhancement Program (SEP and SEP+) and Future Combat System (FCS).

Table III-G-2. Mounted Forces Demonstration and System Summary

ATDs	TECHNOLOGY DEMONSTRATIONS
• Composite Armored Vehicle (CAV)	• Future Combat System Integrated
• Battlefield Combat ID (See *IEW*, Section F)	• Compact Kinetic Energy Missile (CKEM)
• Target Acquisition	• Line-of-Sight Anti-Tank (LOSAT)
• Battlespace Command & Control (BC2) (See C4, Section E)	• Advanced Electronics for Future Combat System
• Hit Avoidance	• Ground Vehicle Distributed Defense
• Direct Fire Lethality	• Future Combat System Mobility
• Future Scout and Cavalry System	• Tank Mobility
• Multifunction Staring Sensor Suite (MFS3)	• Intra-Vehicle Electronics Suite
(For additional information, see Volume II, Annex B.)	

SYSTEM UPGRADES/ADVANCED CONCEPTS	
System Upgrades	***Advanced Concepts***
• M1A2 Abrams SEP	• Future Infantry Vehicle (FIV)
• M1A2 Abrams SEP+	• Future Combat System (FCS)
• M2A3 Bradley PIP	• Future Scout and Cavalry System (FSCS)

Figure III-G-1. Roadmap for Mounted Forces Systems Modernization



*System Upgrade

b. AVT Survivability and Protection Demonstrations

Composite Armored Vehicle (CAV) ATD (94-98). The CAV ATD will demonstrate the feasibility of producing lighter weight ground combat vehicles manufactured from advanced composites. The CAV ATD will consist of an integrated demonstration of advanced composites and advanced lightweight armors on a C-130 air deployable 22-ton vehicle emphasizing manufacturability, repairability, non-destructive testing and structural integrity. The vehicle structure and armor will weigh at least 33 percent less than comparable steel or aluminum. CAV's operational advantages will improve survivability through inherent signature reduction of composite materials on vehicle shaping, and improve agility and deployability by reducing structure and armor weight. **Supports:** Crusader PIPs, Future Scout and Cavalry System (FSCS), Future Combat Systems Demos, and Future Infantry Vehicle (FIV).

Hit Avoidance ATD (95-97). Through BDS Warfighter experiments, the Hit Avoidance ATD will demonstrate the improved battlefield effectiveness, and develop battlefield tactics for integrated hit avoidance technology, to include sensors, countermeasures and active defenses, against both top attack and horizontal threats. The types of sensors considered for integration include laser warning, radar warning, and passive missile warning receivers. Countermeasure candidates include jammers, obscurants, false target generators, and counterfire.

The Hit Avoidance ATD will produce a Commander's Decision Aid (CDA) which can be battlefield tailored to a specific set of threats encountered; it can also be used horizontally across multiple combat and tactical vehicles. The CDA is a Hardware/Software Logic Module that fuses sensors with countermeasures for automated and/or aided crewman response. It is a key component of vehicle protection architecture. The ATD will also produce and field-demonstrate a low cost active protection system. **Supports:** Crusader, FSCS, M1A2 Abrams SEP/SEP+, and M2A3 Bradley.

c. AVT Mobility and Electronics Demonstrations

Target Acquisition ATD (95-98). This ATD will demonstrate automated wide-area search and target acquisition, prioritization, and tracking at extended ranges. Automation of these capabilities will reduce crew workload, shorten timelines to acquire targets, and as a result effectively direct fire. The ability to automatically acquire and hand over targets supports the design of a combat vehicle with fewer crew members, which is more lethal and more deployable, with improved situational awareness through the digitized battlefield.

The Target Acquisition ATD will be composed of a second generation thermal imaging sensor, a millimeter wave radar with Moving Target Indicator (MTI) capability, a multi-functional laser (rangefinding, laser designating, and high density profiling mode), and a day TV. The sensors will be complemented by the inclusion of aided target recognition algorithms and a high-density processor which will run the algorithms. **Supports:** FCS Demos, FSCS, FIV, and M1A2 Abrams SEP/SEP+.

Battlespace Command and Control ATD (97-00). This ATD will demonstrate the capability to integrate, distribute, and graphically display numerous types of digitized command and control information (e.g., terrain, pos/nav, weather, intelligence). For details see *C4*, Section E.

Intra-Vehicle Electronics Suite Technology Demonstration (97-00). This TD will develop and demonstrate a ground vehicle integrated electronic architecture. This effort complements the crewstation designs developed in the Crewman's Associate ATD, completed in FY96, by providing the required electronic architecture. Advanced Warfighting Experiments on the M1A1 Abrams will validate the real-time performance requirements of the Vetronics Open Systems Architecture (VOSA). **Supports:** FSCS, FCS Demos, and M1A2 Abrams SEP/SEP+.

Multifunction Staring Sensor Suite ATD (98-01). This ATD will demonstrate a modular, reconfigurable Multifunction Staring Sensor Suite (MFS3) that integrates multiple advanced sensor components including staring infrared imager, a multifunction laser, and acoustic arrays. The MFS3 will provide scout/cavalry vehicles and amphibious assault vehicles with a compact, affordable sensor suite for long-range noncooperative target identification, mortar/sniper fire location, and air defense against low signature targets. The infrared imaging system will be configured to accommodate either visible to mid infrared or far infrared focal plane arrays. As single focal planes capable of operating across the full optical spectrum mature, these may be inserted into the assembly. The staring infrared sensor will operate at high field rates to allow sniper and mortar detection in addition to the conventional target acquisition functions. Integration of a multifunction, multiwavelength laser system will incorporate ranging, range mapping, target profiling, and laser designation to support target location, target cueing, aided target identification, and target designation. The acoustic array will provide target cueing and location and will assist in automated targeting functions. **Supports:** FSCS, FIV, FCS.

Tank Mobility Technology Demonstration (98-03). This effort will laboratory demonstrate critical engine, electronic drive, track and suspension technologies to support the mobility field demonstrations of the Future Combat System. The electronic drive technology will be developed through a joint effort (DARPA, DA, and USMC) and will produce generators, storage devices (flywheels, batteries, capacitors) and power electronic switching devices. Engine development work will focus on high power density, low heat rejection, single cylinder diesel engine technology efforts directed toward an extremely compact propulsion system. Track improvements will include advance track and track retention system. The suspension technology development will include semi-active/active hydropneumatic and active electric suspension systems. These mobility advancements will enhance system survivability and operational effectiveness through smaller and ligher systems, improved ride quality, increased agility, improved platform stability, reduced acoustic and IR signatures, and silent operations capability. **Supports:** Abrams Upgrades, FIV.

d. AVT Systems Integration Demonstrations

Future Scout and Cavalry System (FSCS) Advanced Technology Demonstration (98-02). The FSCS ATD will demonstrate the feasibility and operational potential of an advanced lightweight vehicle chassis integrating Scout-specific and advanced vehicle technologies developed in other technology base programs. The effort will be fabricated and tested in virtual and real environments to both evaluate and validate sensors/situational awareness capabilities and develop scout tactics. Specific technologies which may be integrated into the Scout platform include: multifunction staring sensor suite, advanced lightweight structural materials and armors, electric drive, lightweight track, semi-active suspension, advanced crew stations, advanced command and control, medium-caliber weapon, and advanced survivability systems.

The FSCS ATD will develop and demonstrate Scout-specific mobility components such as electric drive, semi and fully active suspension, and band track. This effort will validate the inherent signature reduction of advanced mobility technologies. The FSCS ATD will transition in FY02 to the Future Scout and Combat System (FSCS), an EMD program. **Supports:** FSCS.

e. Demonstrations Supporting Future Combat System (FCS)

Advanced Electronics for Future Combat System (99-04). This effort will upgrade the VOSA developed under the Intra-Vehicle Electronics Suite ATD to support high-power electronic devices. Devices that will require such power include Electro-Magnetic Gun, Electro-Magnetic Armor, and Electric Drive. Testing, demonstration, and validation of the upgraded VOSA will be performed in a high-power electronics Vehicle Systems Integration Lab (VSIL) prior to integration on the Future Combat System Integrated Demo. This effort will also identify, develop, and demonstrate the required crewstation upgrades. **Supports:** FCS.

Future Combat System Integrated Technology Demonstrator (00-05). This effort will demonstrate the integration of the full suite of FCS technologies. It will include Distributed Defense, Advanced Mobility, and fully integrated electronics subsystems. The main thrust of this TD is to demonstrate the high-power electric technologies critical to the realiation of "leap ahead" capabilities as an integrated system within a combat vehicle. This TD will also demonstrate the integration and operation of these electrical components in a combat vehicle and will provide the basis for measuring component performance, evaluating electrical system architectures, and ensuring compatibility with other TDs. **Supports:** FCS.

Ground Vehicle Distributed Defense (01-04). This effort will demonstrate a distributed defense system that is capable of protecting armored forces against attack by smart and precision guided weapons. It will reduce cost and enhance force survivability by putting select sensors and countermeasures on some, rather than all, of the vehicles in the force. Sensors, electronic countermeasures, and active protection will be considered. Most, if not all, Sensor/CM/C2 technologies will either be COTS available or available from other DoD agencies. **Supports:** FCS, FSCS, Abrams, and Bradley.

Future Combat System Mobility (02-06). This effort will develop and demonstrate an advanced propulsion system which consists of a high power density, low heat rejection, engine (Diesel or Turbine); an electric drive and power conditioning system; an active suspension system; an automatic track tensioning system; and an advanced track. This propulsion system will meet the requirements of the Future Combat System and main weapon. Improvements in operational effectiveness will be field demonstrated.

Increased cross-country mobility and platform stabilization will be achieved with either a fully active suspension using electric actuators or a semiactive/active hydropneumatic suspension. Improved survivability and the silent operation capability of the electric drive system will be demonstrated.

The electric drive hardware to be integrated will be funded primarily by DARPA and managed jointly by the Army and Marines. The advanced engine, track, and suspension will be developed at TARDEC. By FY06, TARDEC will complete integrated mobility system and durability demonstrations. **Supports:** FCS.

f. Ground Vehicle AVT Demonstrations (Outside the AVT Umbrella)

Battlefield Combat ID ATD (93-98). This ATD's focus is on fratricide reduction and is discussed in the *IEW* Section of this chapter (Section III.F).

Compact Kinetic Energy Missile (CKEM) Technology Demonstration (96-99). This TD will develop a lightweight miniature (35-40kg) hypervelocity KE missile, compatible with the LOSAT target acquisition and tracking system and could be compatible with the fire control system for close combat and short range air defense missions. It will demonstrate increased flight maneuverability against close-in airborne targets with continuous control actuation for significantly reduced minimum range and increased missile platform adaptability. Demonstration of this miniature hypervelocity missile concept will provide capability for a significant increase in lethality, survivability, and mobility of a dual role close combat and short range air defense KE weapon system that is easily stowable on tracked combat vehicles. **Supports:** FCS and FIV.

5. Relationship to Modernization Plan Annexes

Figure III-G-2 exhibits the cross-fertilization that exists between SU/ACs and several Army Modernization Plan Annexes. All of the SU/ACs, ATDs, and technology demonstrations presented in this section support the Army Mounted Forces modernization areas; many of them support additional modernization areas.

Figure III-G-2. Correlation Between Mounted Forces SU/ACs and Other Army Modernization Plan Annexes

MOUNTED FORCES SYSTEM UPGRADES/ADVANCED CONCEPTS		MODERNIZATION PLAN ANNEXES: Fire Support	Close Combat Light	IEW	C4
System Upgrades	M1A2 Abrams SEP	○		○	●
	M1A2 Abrams SEP+	○		○	●
	M2A3 Bradley PIP	○	○	○	●
Advanced Concepts	Future Combat System (FCS)	○	○	○	●
	Future Scout & Cavalry System (FSCS)	●	●	○	●
	Future Infantry Fighting Vehicle (FIFV)	○	○	○	●

● System plays a significant role in the Modernization Strategy.

○ System makes a contribution to the Modernization Strategy.

H. Close Combat Light

Those experimenting today will lead modernized units tomorrow.

Togo D. West, Jr.
Secretary of the Army

1. Introduction

In light of the changing threat, the Army is placing increased emphasis on developing a more flexible, combat ready military force that can respond quickly to any crisis situation, capable of deterring aggression and, should deterrence fail, of defeating the enemy throughout the operational continuum. The cornerstone of this flexible force is the Army's Light Forces. The Light Forces are comprised of combat, combat support, and combat service support units that participate in and support the close battle. Their mission is to defeat threat forces in a low-intensity conflict, while retaining a capability for employment in mid to high intensity conflicts and Operations Other Than War (OOTW). Light Forces are the "option of choice" for peacetime engagement and conflict prevention. We must take advantage of new technologies and field equipment that is more lethal, survivable, maintainable, smaller, lighter weight, and easily transportable.

Previous military operations demonstrated the need for rapid deployment and insertion of light forces as the "first-to-fight." In dealing with regional and urban conflicts, the prepositioning of equipment is less practical than it was in Europe. Operation Desert Storm exposed the vulnerability of our "first-to-arrive," lightly equipped contingency forces (airborne, in the case of the Army) to Third World threats equipped with heavy armor.

All elements of the future advanced land combat force must be highly deployable, able to execute missions outside the operational envelope of opposing forces, and survive against "a myriad of lethal anti-armor weapons" and other non-traditional, non-lethal weapons.

2. Relationship to Operational Capabilities

It may be necessary for light forces to conduct military operations under a variety of conditions generated by a wide range of threats. We must, therefore, continue to leverage technology in the following key areas to ensure our capabilities exceed those of our current and potential threats:

- Integrate digitization
- Provide smaller, lighter, precision fire power
- Facilitate mobility and maneuver
- Maximize leadership and training
- Increase protection

A major Army initiative, designed and geared towards achieving U.S. Light Forces superiority is the Rapid Force Projection Initiative (RFPI) Advanced Concept Technology Demonstration (ACTD). This ACTD explores new tactics and technologies via a "System of Systems" approach providing a path to an air deployable, early entry light force that is significantly more capable of destroying a heavy armored threat beyond traditional direct fire weapons. The RFPI concept includes a variety of advanced sensors (air and ground, manned and unmanned), several precision guided, non-line-of-sight weapons, responsive command and control mechanisms, and automated targeting. Target handover will be facilitated by tactical digital data transfer systems now being developed as part of the U.S. Army Battle Command System (ABCS) program. Specifically, this ACTD will provide the opportunity to explore the integration of new technologies with modified tactics, technologies and procedures to improve the survivability of our early entry forces.

The Light Forces are key elements of the U.S. forward deployed, crisis response, and reinforcing forces. Light Forces provide versatility in two ways: they are rapidly deployable and they are most suited for fighting in close terrain. These characteristics enable light forces to be used in all of the Army's roles and missions. Some examples of these are:

- *Initial forward deployment and the timely reinforcement of forces.* This has deterrent value and sends a message of resolve in a crisis situation, yet is not perceived as escalatory.

- *Contingency crisis situations*, where a rapid and decisive deployment can forestall or limit hostilities. In an area where no infrastructure exists, a forced entry and subsequent rapid build-up of force may be required.
- *Nation building/military operations other than war.* Nations involved in low-intensity conflicts may require economic and social-political solutions. Light forces are ideally suited in the role of providing security and promoting the political and social development of nations. Their inherent characteristic of low equipment density does not create an impact on a developing country, yet it provides a widespread sense of security.
- *Counter Terrorism* can be used both domestically and internationally. It may require special non-traditional methods.

Table III-H-1 represents Close Combat Light Systems/System Upgrades/Advanced Concepts (S/SU/ACs) capabilities that provide either significant or some capability to Battlefield Dynamics. This table also provides highlights of capabilities provided by other Army modernization programs discussed in detail throughout this chapter.

3. Modernization Strategy

The Combat Maneuver Annex to the Army Modernization Plan (AMP), of which Close Combat Light is a part, reviews the requirements placed on the light forces over the entire spectrum of potential future conflicts and is the Army's strategy for modernization of its strategically flexible Light Forces. The Close Combat Light modernization strategy focuses on new materiel which increases lethality, mobility, and survivability while correcting deficiencies and providing the necessary tailorability across the spectrum of conflict. Priority is given to equipment which significantly increases flexibility and survivability.

Early entry forces will gain increased lethality and survivability against heavy forces through application of the Hunter-Standoff Killer concept, i.e., use of advanced forward sensors (hunters) and standoff weapons (killers), that will be demonstrated in a system of systems which can engage enemy forces at ranges beyond their ability to counter.

Close Combat Light extracts those portions of all other modernization plans and mission areas that are applicable to Light Forces, examines them from the perspective of the Light Forces roles and missions, and ensures the Light Forces are provided adequate resources.

This plan is the result of a thorough examination of the threat, the nature and imperatives of the future battlefield, a recognition of the need to significantly reduce the time required to develop and field advanced technology systems, and the recognition of time-constrained resources. The plan captures the technology and systems that will make a significant contribution to the deterrent value of light forces and/or provide "leap-ahead" capabilities. The objective is to provide a disciplined evolution of the Army Light Forces to meet the future battlefield requirements of increased firepower, flexibility, mobility, survivability, and sustainability.

4. Roadmap For Close Combat Light

Table III-H-2 is a summary of Close Combat Light demonstrations and systems.

Because Close Combat Light is primarily an integration plan, the applicable S/SU/ACs along with the majority of appropriate ATDs and technology demonstrations which provide capabilities to the Close Combat Light mission are shown on the existing roadmaps throughout the rest of Chapter III, and are not repeated here.

The Rapid Force Projection Initiative (RFPI), however, is unique to Close Combat Light and is displayed in Figure III-H-1a. It depicts the Army ATDs and technology demonstrations that support the RFPI ACTD in the form of capabilities provided by systems or system upgrades.

In addition to the RFPI demonstrations, there are other technology demonstrations that are unique to the Close Combat Light Mission area, to include non-lethal weapons. These are shown in the roadmap on Figures III-H-1b and III-H-1c.

Table III-H-1. Close Combat Light System Capabilities

S/SU/AC	Early Entry	Depth and Simultaneous Attack	Mounted Battlespace	Dismounted Battlespace	Battle Command	Combat Service Support	SYSTEM/SYSTEM UPGRADE CAPABILITIES	ADVANCED CONCEPT CAPABILITIES
AVIATION							• Light attack/armed recon • Day/night and adverse weather • Anti-armor/air-to-air • Aided target recognition • Advanced survivability • Self deployability	• Ground maintenance associate • Increased payload • Advanced transmission • Man-machine interface • Increased lethality • All weather NOE pilotage • Multirole/versatility • Automatic target recognition • Signature control • Adv. maneuverability/agility • Advanced propulsion • Integrated flight/fire control • Precision navigation • NOE sling load operations
System								
RAH-66 Comanche	●	●	●	●	○			
System Upgrade								
AH-64 Apache Longbow	●	●	●	●	○			
UH-60 Blackhawk	●	●	●	●	○			
Advanced Concepts								
Improved Cargo Helicopter	●	●	●	●		●		
Enhanced AH-64 Apache	●	●	●	●	○			
Joint Transport Rotorcraft	●	●	●	●		●		
Bird Dog	●	●	○	○				
COMMAND, CONTROL, COMMUNICATIONS, AND COMPUTERS							• Distributed processing and data bases • Integrated system management • Gateways and multilevel security • Jam resistant capability • High mobility and survivability • Expert system planning aids • Battlefield visualization • Assured communications	• Enhanced situation awareness • Synchronized battle management • Voice input/output • Seamless, transparent communication • Secure multimedia • Automated network management • C2 on the move • Integrated sensor weapon C3
System Upgrades								
Communication—Wide, Local, Mobile	●	●	●	●	●	●		
Advanced Concepts								
Force XXI/Vision 2010	●	●	●	●	●	●		
INTELLIGENCE AND ELECTRONIC WARFARE							• Manpack/vehicle for surveillance/ targeting • Penetration and standoff IEW • Automated terrain identifier • ELINT, COMINT, EA radar multi-sensor package • Automated weather decision aids • Manportable sensor to detect, track, and classify vehicle and personnel	• Integrated system of sensors and collectors —multispectral —advanced processing • Information dissemination —multi-echelon —close loop target handover • Intelligence analysis and assessment
Systems								
Ground-Based Common Sensor – Light*	○	○		○				
UAV Tactical Intelligence Package		●	○	●				
System Upgrade								
Integrated Meteorological System		●	○	○	●	○		
Advanced Concept								
Dist. IEW Fusion		○	●	○	○			
MOUNTED FORCES								• Advanced fire control • Advanced armament • Passive/active protection • Lighter forces • Integrated munitions/fuel/cargo transfer • Composite structures • Reduced vehicles signatures/weight
Advanced Concepts								
Future Scout & Cavalry System	●	●	●	●	●			
Future Infantry Fighting Vehicle	○		●	●	●			
Future Combat System	○		●	●	●			
CLOSE COMBAT LIGHT							• Dismounted infantry combat power • Increased capability of vehicle-mounted support weapons • Increased self-protection	• Increased payload • Increased lethality • Enhanced situation awareness • Integrated system of sensors • Improved PH • IR/TV sensor • Lightweight • Ability to accurately deliver supplies/ equipment from offset distances • Increased delivery accuracy • Covert, day/night, and limited visibility airdrop capablity
Systems								
Obj Crew Served Weapon	●		○	●				
System Upgrade								
Advanced Precision Airborne Delivery System	●			●		●		
Advanced Concept								
Precision Offset High Glide Aerial Delivery of Munitions and Equipment	●	○		●		●		

(Continued)

● Provides significant capability ○ Provides some capability *Contains Com-Jam capability

Table III-H-1. Close Combat Light System Capabilities (Continued)

S/SU/AC	Early Entry	Depth and Simultaneous Attack	Mounted Battlespace	Dismounted Battlespace	Battle Command	Combat Service Support	SYSTEM/SYSTEM UPGRADE CAPABILITIES	ADVANCED CONCEPT CAPABILITIES
	BATTLEFIELD DYNAMICS							
SOLDIER							• Optimal food mix—quality and amount • Improved soldier and crew protection • Improved accuracy, effects, and logistics • Battery unit/engine fuel cell, light-weight power source • Thermal weapon sight to detect man-sized targets • Soldier computer • Increased accuracy, Ph, and range • Lightweight system	
Systems								
Obj. Family of Small Arms	●		○	●	●	○		
Land Warrior	●		○	●	●	○		
Obj. Sniper Weapon	●	○	○	●	○	○		
System Upgrades								
Land Warrior	●		○	●	●	○		
Army Field Feeding Future	●		○	●		●		
Objective Individual Combat Weapon	●	○	○	●	○	○		
Objective Crew Served Weapon	●	○	○	●	○	○		
COMBAT HEALTH SUPPORT							• Anti-malaria drug for drug-resistant malarias • Vaccine for hemorrhagic fevers • Tissue adhesives for hemorrhage control • Reduction and prevention of operational stress • Anti-endotoxin antibody for heat stroke treatment • Ricin subunit vaccine • Botulinum toxoid • Staphyloccal Enterotoxin B (SEB) toxoid • Rapid Identification/Diagnosis Kit • Cyanide pretreatment	• E. Coli Shigella Sonnel Hybrid vaccine • Paromomycin, topical antileishmaniald drug • HIV vaccine for vaccine therapy • Immunization against biological threat agents • Pre-treatment against biological threat agents • Advanced anti-convulsant • Reactive topical skin protectant • Microwave warmer for resuscitation fluid and blood
Systems/System Upgrades/ Advanced Concepts								
Medical Defense Against Infectious Disease	●	○	●	●	○	●		
Combat Casualty Care	●	○	●	●	○	●		
Army Operational Medicine	●	●	●	●	●	●		
Medical Biological Defense	●	○	●	●	○	●		
Medical Chemical Defense	●	○	●	●	○	●		
NBC							• Decon downtime reduced • Detection and ID of all CB threat agents • Low bulk, low cost CB protective mask • Multispectral smoke material to defeat enemy RSTA assets • Defeat or degrade enemy armored targets • Improved entry/exit	• Defeat/immobilize enemy threat equipment, i.e., trucks, tanks • Close-in fire support for SOF, MOUT • Increased first kill capability of hardened targets • Large area defeat of enemy threat equipment • Counter-counter battery • Target marking
Systems/System Upgrades/ Advanced Concepts								
Individual Protection	●		○	●		○		
Collective Protection	●		●	●	●	●		
Chemical Detectors	●		●	●	●	●		
Biological Detectors	●		●	●	●	●		
Smoke/Obscurants	○	○	●	●		●		
Decontamination	●		○	○		●		
Target Defeat Capabilities	○	●	●	●				
AIR DEFENSE								• IR counter-countermeasures • Improved lethality against helicopters • 360° coverage
Advanced Concept								
Stinger Block II	●	○	○	●	●	○		
SPACE							• Digital battlefield communications • Mid- and high-capacity voice, data • Improved weapons pointing • Laser boresight • Anti-satellite capabilities	
System								
Joint Tactical Ground Station	○	●	○	○	●	○		
System Upgrades								
SCAMP Terminals	○	○	○	○	●	○		
Tactical Exploitation of National Capabilities	●	○	○	○	●	○		
Advanced Concepts								• High-capacity voice, data, video • Theater direct access terminals • EW, DEW, KEW systems
Communications Transport	○	○	○	○	●	○		
Advanced Image Collection and Processing	○	○	○	○	●	○		
Force XXI	○	○	○	○	●	○		

● Provides significant capability ○ Provides some capability

(Continued)

Table III-H-1. Close Combat Light System Capabilities (Continued)

● Provides significant capability ○ Provides some capability

S/SU/AC	Early Entry	Depth and Simultaneous Attack	Mounted Battlespace	Dismounted Battlespace	Battle Command	Combat Service Support	SYSTEM/SYSTEM UPGRADE CAPABILITIES	ADVANCED CONCEPT CAPABILITIES
	BATTLEFIELD DYNAMICS							
ENGINEER AND MINE WARFARE							• Linear clearning of mines using explosives • Upgraded mine detector • Improved minefield effectiveness • Neutralize anti-tank mines • Detection avoidance • Counter threat thermal IR sensors • Integrated, cooperative, controllable two-way minefield • Detect mines with large lethal radii	
Systems								
Vehicular Mounted Mine Detector	●	●	●	○		●		
Intelligent Minefield	●	●	●	●	●	●		
Mine Hunter Killer	●	●	●	○		●		
System Upgrades								
Low Cost Low Observable Technologies	●	●	●	●	●	●		
Digital Topographic Support System/Quick Response Multicolor Printer	●	●	●	●	●	●		
FIRE SUPPORT							• Improved range, agility, and RAM • Extended range kill • Increased sensor accuracy • Decision aids • Smart weapons	• Mobile long-range capability • Improved targeting • Precision guidance capability • Lightweight, deployable, long range • Increased lethality and accuracy • Reduced fire mission duration • Reduced logistics burden
Systems								
Crusader		●	●		●	●		
System Upgrades								
FireFinder P3I	○	●	○	○	●			
Multi-Mode Airframe Technology	●	●	○	○				
Advanced Concepts								
155mm Automated Howitzer	●	●	●					
Precision Guided Mortar Munition	●	○	●	●				
Guided MLRS	●	●	○	●	●	●		
LOGISTICS							• Shelf stable ration components • Enhanced rations performance and flexibility • Reduced manpower • Improved quality of life • Improved precision guided delivery of munitions • Automated logistics planning	• Automated logistics planning and execution • Total asset visibility • Accurate delivery of supplies/ equipment from offset distances • Increased delivery accuracy via an autonomous GPS-based guidance and navigation system • Covert day/night and limited visibility air drop capabilities
System Upgrades								
Aerial Delivery	●	○		●		●		
Army Field Feeding Future	○		○	○		●		
Rapid Deployable Food Service for Force Projection	●		○	○		●		
Logistics Survivability	●	●	●			○		
Electric Power Generation	●	○	○	○		●		
Advanced Concepts								
Precision Offset, High Glide Aerial Delivery	●	●		●		●		
Total Distribution System	●	○	○	○	○	●		
Munitions Survivability	●	●	○	○	○	●		
TRAINING							• Joint/combined exercises • Unique DIS-based Reserve Component training strategies • Combined Arms Training • Battle Command Training • Upgrade of MILES equipment • Synthetic battlefield	• Joint mission training • Mission rehearsal • Mission readiness estimation • Behaviorally-accurate SAFOR
System Upgrades								
Distributed Interactive Simulation	●	●	●	●	●	●		
Combined Arms Training Strategy	○	●	●	●	●	●		
Combat Training Centers	●	●	●	●	●	●		
Non-Sys Training Devices (NSTD)	●	●	●	●	●	●		
Range Instrumentation Targetry Devices			●	●	●			
Combined Arms Tactical Trainer	○	●	●	●	●	●		
Advanced Concepts								
Dist. Models/Sim for Joint/Theater Exercises	●	●	●	●	●	●		
Innovative Sim-Based Training Strategies	●	●	●	●	●	●		
Advanced Assessment and Leader	●	●	●	●	●	●		

Table III-H-2. Close Combat Light Demonstration and System Summary

RAPID FORCE PROJECTION INITIATIVE ATDs	TECHNOLOGY DEMONSTRATIONS
• Hunter Sensor Suite • Precision Guided Mortar Munition • Intelligent Minefield (see *EMW*) • Guided MLRS (see *Fire Support*) • Enhanced Fiber Optic Guided Missile (EFOGM) **ACTDs** • Rapid Force Projection Initiative (RFPI) (For additional information, see Volume II, Annex B.)	**RFPI Demonstrations** • Aerial Scout Sensor Integration • Integrated Acoustic System (IAS) • Autonomous Intelligent Submunition (AIS) (see *Fire Support*) • RFPI Command and Control • Future Missile Technology Integration (FMTI) • High Mobility Rocket System (HIMARS) • 155mm Automated Howitzer (see *Fire Support*) **CCL Unique Demonstrations** • Objective Crew-Served Weapon • Counter Active Protection System (CAPS) • Precision Offset, High Glide Aerial Delivery of Munitions and Equipment **Non-Lethal Demonstrations** • Non-Lethal Marker Munition • 12 Gauge Round • Electric Water Cannon • Mid-Sized Riot Control Dispenser • Non-Lethal Entanglement • Electric Vehicle Stopper
SYSTEMS/SYSTEM UPGRADES/ADVANCED CONCEPTS (Unique to Close Combat Light)	
System • Objective Crew Served Weapon ***System Upgrades*** • Advanced Precision Airborne Delivery System	***Advanced Concepts*** • Precision Offset, High Glide Aerial Delivery of Munitions and Equipment

a. RFPI Sensor Demonstrations

Aerial Scout Sensor Integration Technology Demonstration (95-98). This TD will demonstrate technology to provide light forces with accurate, timely, "over-the-hill" reconnaissance, surveillance and battle damage assessment capability through use of aerial sensors enhanced with aided target recognition and smart workstation technologies. A variety of imaging sensors will be used on a surrogate aerial platform as well as a ground-based image exploitation workstation. Candidate sensors include FLIR, infrared linescanner, day TV and MTI radar. The goal is to demonstrate a reduction in data timelines, from tasking to output of tactical information. **Supports:** RFPI ACTD.

Hunter Sensor Suite ATD (94-97). This ATD will demonstrate the feasibility of a lightweight, deployable, and survivable Hunter Vehicle platform with an advanced long-range sensor suite for a lightweight, deployable vehicle. Aided target recognition for acquiring multiple targets and enhanced target handoff will result from this demonstration. The suite will combine a second generation thermal imager, day TV, eyesafe laser rangefinder and imbedded ATR processor, video compression and communications interface for linkage into a C3 net. This effort will develop and demonstrate the communications data compression techniques/technologies to permit transmission of the imagery over existing combat net radio systems. A Hunter Vehicle (HV) will be designed to accept the integration of signature management technologies and the Hunter sensor suite. **Supports:** RFPI ACTD.

Integrated Acoustic System (IAS) (96-99). This TD will demonstrate acoustic sensor technology in both hand-emplaced and air-droppable variants. Advanced acoustic sensor efforts ongoing in the Intelligent Minefield ATD (see *EMU*, Section M) will provide the hand-emplaced system. The Air Deployable Acoustic Sensor (ADAS) system will be developed to provide a helicopter-deployable variant. Both systems will be demonstrated during the RFPI

Figure III-H-1a. Close Combat Light Roadmap for Rapid Force Projection Initiative ACTD

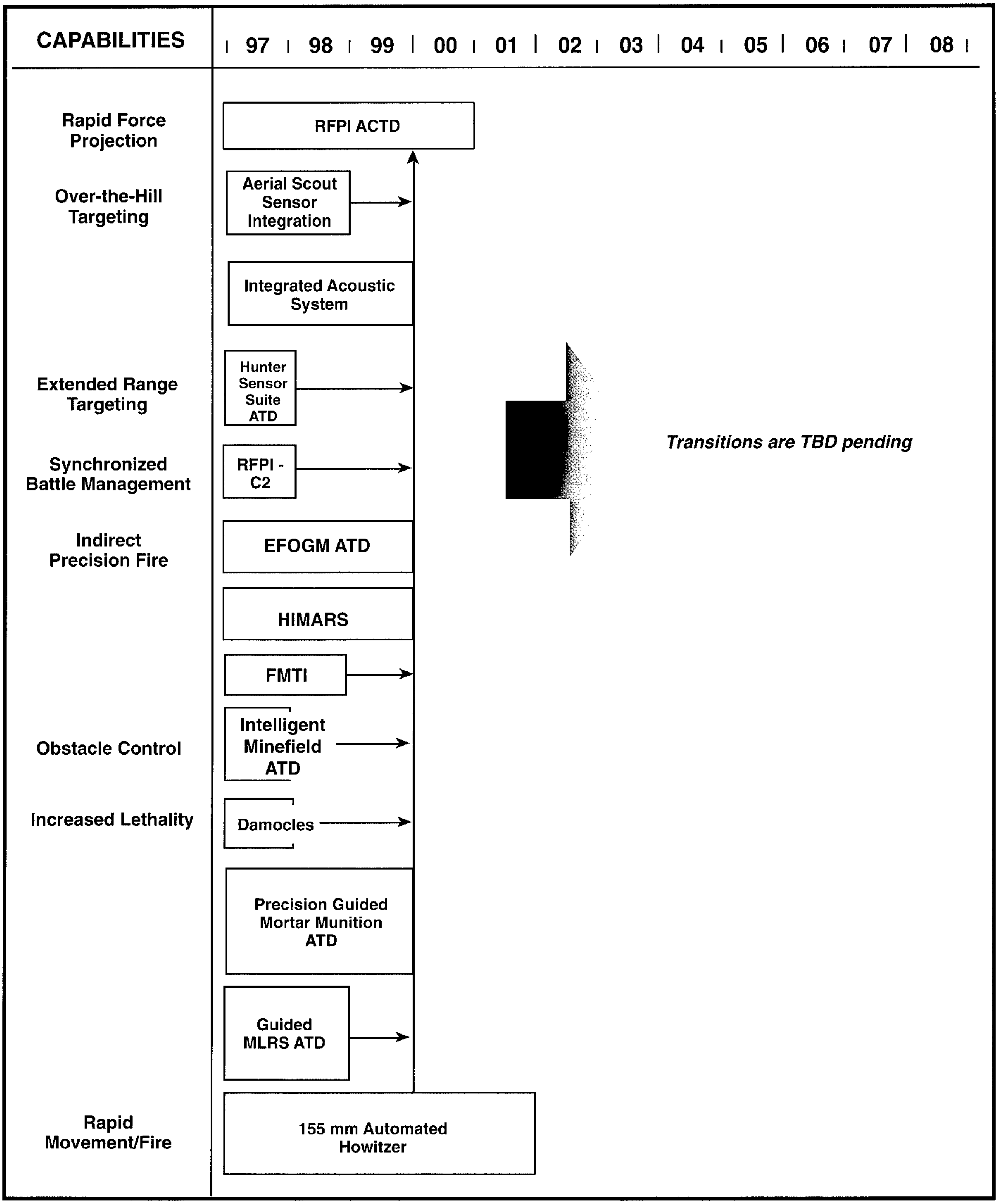
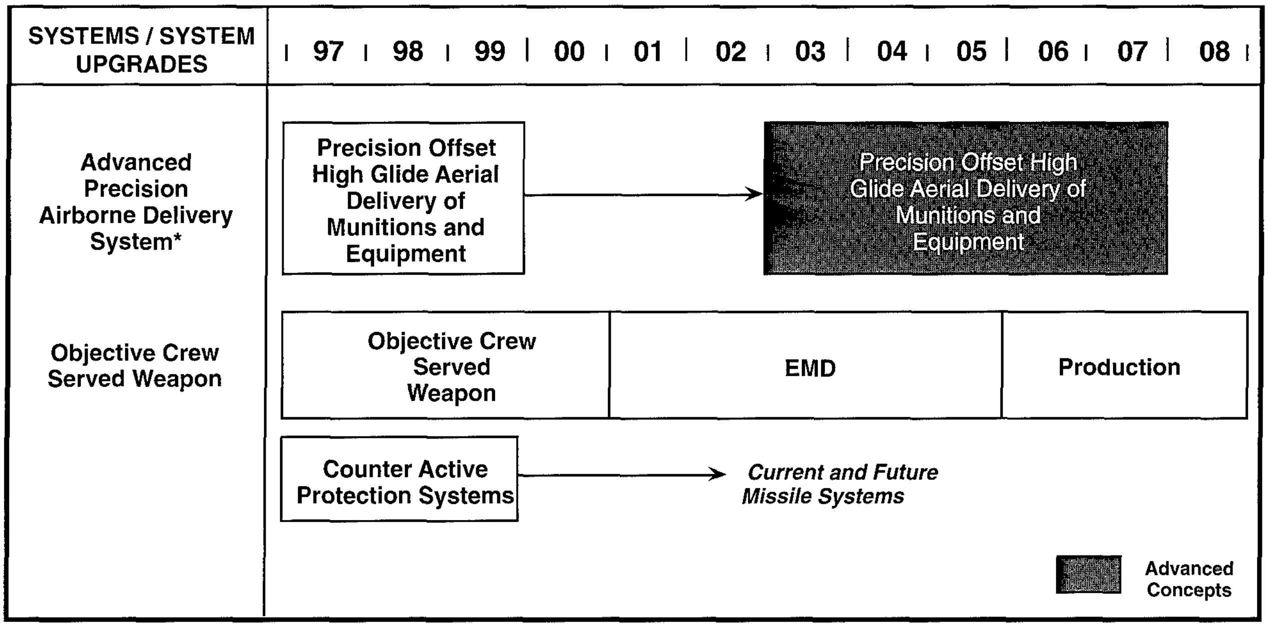
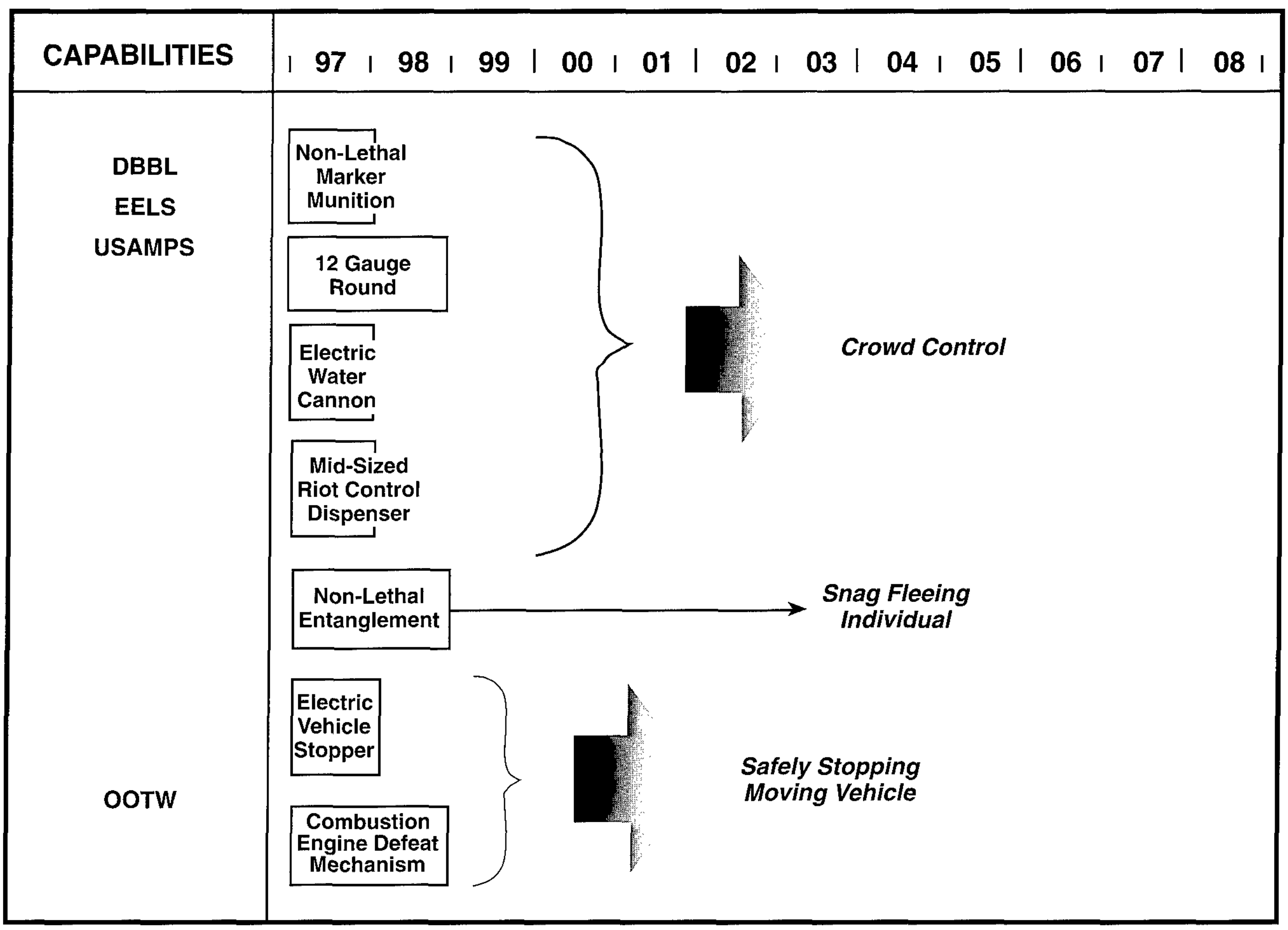


Figure III-H-1b. Roadmap for Demonstrations Unique to Close Combat Light



* System Upgrade

Figure III-H-1c. Roadmap for Non-Lethal Demonstrations



ACTD large-scale field experiment. **Supports:** RFPI ACTD.

Autonomous Intelligent Submunition (AIS) (94-97). See *Fire Support* section, III-N. **Supports:** RFPI ACTD.

b. RFPI Command and Control Demonstration

RFPI Command and Control (C2) Technology Demonstration (94-97). The RFPI program of Advanced Land Combat will demonstrate enhanced capabilities which address the strategy of Close Combat Light with respect to the rapidly deployable force. The C2 portion of this program will demonstrate the integration of rapid force projection remote scout and sensor reconnaissance information into the Battlespace C2 concept, providing commanders with the ability to integrate data into the overall battlefield picture, set target priorities, determine target weapon pairings, and perform target handover to non-line-of-sight, air attack, or close weapon systems. Demonstrations will encompass the data links required to transport targeting data from remote sensors to an operations center, and the ability to redistribute the correlated targeting data to a decision point and to various weapon platforms which would bring fire on given targets. Various transmission technologies will be investigated: wide band data links, packet techniques, bandwidth compression, and alternate frequency bands. **Supports:** Battlespace C2 and RFPI ACTD.

c. RFPI Advanced Concept Technology Demonstration

RFPI ACTD (95-00). The RFPI ACTD will demonstrate a highly lethal, survivable, and rapidly air deployable enhancement to the Early Entry Task Force. This enhancement will provide automated target transfer from forward sensors to an indirect fire weapon system with the capability to engage high value targets beyond traditional direct fire ranges. The ACTD provides an opportunity for extensive user interaction with the new RFPI hunter-standoff killer concept and its emerging technologies. A selected light, air assault, or airborne unit from Forces Command (FORSCOM) will demonstrate the RFPI ACTD concept, and will retain selected equipment for at least a 2-year extended demonstration period to provide residual capabilities and allow arrangements for long-term retention. The ACTD leverages maturing RFPI sensor technologies and an advanced command and control element. The ACTD includes automated Fire Control System (FCS) for selected Howitzers, the Enhanced Fiber-Optic Guided Missile (EFOGM) non-line-of-sight weapon system, and the High Mobility Artillery Rocket System (HIMARS). It encourages user exploration of a variety of baseline procedures to optimize utility of the new hunter standoff killer concept. **Supports:** RFPI.

d. RFPI Weapons Demonstrations

The RFPI Large Scale Field Experiment includes several advanced concepts which will demonstrate the System of Systems concept of hunters and standoff killers. During this timeframe, the newly configured and upgraded EFOGM and 155mm Automated Howitzer (with automated fire control system) will be demonstrated. Other new hunter or killer technologies will be considered during this phase.

Enhanced Fiber Optic Guided Missile (EFOGM) ATD (94-99). This ATD will develop and demonstrate a remotely directed (fiber optically guided) missile system (EFOGM), modified with an Imaging IR (I2R) seeker, Inertial Navigational System, and other data link modifications. It will defeat armor out to ranges of 15 km and permit the operator, through a fiber-optic guidance link to the missile seeker, to search for targets in the extended close battle area. The system has the unique ability to operate from defilade and to engage targets which are also in defilade. Friendly target recognition capability and fratricide avoidance is enhanced with a gunner operator in the loop. The EFOGM ATD will provide the advanced, non-line-of-sight weapon to be demonstrated under the RFPI ACTD. This ACTD will integrate light force organic weapons, the EFOGM, RFPI sensors, other RFPI standoff killers, and C2. **Supports:** RFPI and JPSD Precision/Rapid Counter MRL ACTDs.

Intelligent Minefield ATD (93-97). This ATD will demonstrate an integrated, cooperative smart (advanced sensors and controls) minefield. See *Engineer and Mine Warfare* (Section III-M) for more detailed information. **Supports:** RFPI ACTD.

155mm Automated Howitzer Technology Demonstration (94-01). The program will develop an advanced digital fire control system for towed artillery. See *Fire Support* (Section III-N) for more detailed information. **Supports:** RFPI ACTD.

Precision Guided Mortar Munition (PGMM) ATD (94-99). The ATD will demonstrate, through live fire and simulation, the ability of a guided mortar munition to defeat armored as well as high value point targets. It will also demonstrate longer range, more accurate, and timely response to requests for fire, through the integration of a lightweight fire control system. As part of the RFPI, the PGMM and fire control will be an advanced concept stand-off killer in the RFPI ACTD. The ATD program consists of a 120mm PGMM capable of finding and defeating enemy armor and other high priority targets in an autonomous role, and a lightweight fire control to improve the accuracy and response time of fielded mortar systems. An initial test bed is being integrated on a HMMWV, with a follow-on effort to reduce the size and weight of the components. The program will focus on the azimuth reference unit and the software required to completely integrate the components and fire a PGMM against moving targets. **Supports:** RFPI ACTD.

Guided MLRS ATD (95-98). This ATD is discussed in detail in *Fire Support*, Section III-N.

High Mobility Artillery Rocket System (HIMARS) Technology Demonstration (95-99). The HIMARS TD will provide a lightweight, C-130 transportable version of the M-270 Multiple Launch Rocket System (MLRS) launcher. Mounted on a 5-ton Family of Medium Tactical Vehicles (FMTV) truck chassis, it will fire any rocket or missile in the MLRS Family of Munitions. The HIMARS uses the same command, control, and communications, as well as the same crew as the MLRS launcher, but carries only one rocket or missile pod. It will roll on and off of a C-130 transport aircraft and, when carried with a combat load, will be ready to operate within minutes of landing. **Supports:** RFPI ACTD and MLRS Family of Munitions.

Future Missile Technology Integration (FMTI) Technology Demonstration (94-98). This technology demonstration is discussed in detail in *Aviation*, Section III-D.

e. Close Combat Light Unique Demonstrations

(Outside of the RFPI Umbrella.)

The Objective Crew-Served Weapon Technology Demonstration (96-00) (part of the Objective Family of Small Arms described in section I, *Soldier*) is unique to the Close Combat Light Section. It will support the two-man, crew-served weapon outlined in the Army Small Arms Master Plan and the Joint Service Small Arms Master Plan. This demonstration will establish the feasibility of a lightweight two-man portable crew-served weapon system with a high probability of incapacitation and suppression out to 2000 meters, against protected personnel targets. It will also have a high potential to damage light vehicles, lightly armored vehicles, water craft, and slow moving aircraft beyond 1000 meters. The fire control system will include a laser range finder, environmental sensors, ballistic computer, day and night channel, and adjusted aimpoint to provide the full ballistic solution. The weapon will fire bursting ammunition to provide decisively violent target effects to overmatch threat systems and will have the ability to defeat defilade or non-line-of-sight personnel targets. The fire control system will be modular in design, eliminate the need to estimate range, provide a full solution aimpoint, and embedded training. This weapon would be utilized by mounted and dismounted combat soldiers. **Supports:** Objective Crew Served Weapon.

Precision Offset, High Glide Aerial Delivery of Munitions and Equipment Technology Demonstration (94-99). This will demonstrate revolutionary technologies for the reliable precision guided delivery of combat essential munitions and equipment using high glide wing technology and incorporating a low cost, modular GPS guidance and control system. This technology will provide a 6:1 or better glide ratio. A modular GPS guidance package was developed and a precision high glide capability of 500-pound payload using semi-rigid wing technology was demonstrated in FY96. By the end of FY99 it will demonstrate precision high glide of a 5,000-pound payload, with a goal of a 10,000-pound payload, using an advanced guidance package and high glide wing. High glide technology will significantly enhance the military aerial delivery capability through substantially higher glide ratios than are possible with ram air parachutes and will directly benefit the initial deployment of Early Entry Forces. **Supports:** RFPI ACTD, EELS and DSA Battle Labs, and Advanced Precision Airborne Delivery System.

Counter Active Protection Systems (CAPS) Technology Demonstration (96-99). The CAPS TD will develop and demonstrate technologies/methods which can be applied to Anti-Tank Guided Weapons (ATGW) for improving effectiveness against threat armor equipped with Active Protection Systems (APS).

Current technology development is concentrated in the following three areas:

- RF Countermeasure (RFCM) technology for jamming or deceiving APS sensors used for detection, acquisition, and tracking.
- Long standoff warheads for shooting from beyond the range of APS fragment-producing countermunitions.
- Ballistic hardening of ATGW to reduce vulnerability to fragment impact.

Supports: Close Combat Anti-Armor Weapon System (CCAWS), Advanced Missile System-Heavy (AMS-H), Javelin, and BAT.

f. Non-Lethal Weapons Technology Demonstrations

Defense Planning Guidance, FY 1995-1999, requires Non-lethal weapons capabilities for light forces. Non-lethal weapons are intended to minimize fatalities and collateral damage to property and the environment. These weapons add engagement options between lethal response and show of force/demonstrations. Because of the increasing trend of U.S. military involvement in OOTW, e.g., Operation United Shield, Military Operations in Built-Up Areas (MOBA), and Military Operations in Urban Terrain (MOUT), there is a need to enhance effectiveness and survivability of U.S. forces engaged in these operations through the application of advanced non-lethal technologies.

The Non-Lethal Technology Demonstrations will provide weapon options which will make the early entry light force significantly more effective against the changing threats. This can be accomplished by adapting advanced technologies for insertion into existing weapons platforms. The use of non-lethal weapons is situation dependent and must be integrated into and support all combat and non-combat functions.

Figure III-H-1c depicts the Army technology demonstrations that support the development of non-lethal weapons and related capabilities provided by the insertion of these weapons into the force structure.

Non-Lethal Marker Munition Technology Demonstration (96-97). This TD will evaluate candidates for dispensability, select dye candidates, and complete munition integration. In FY98, actual firing tests at 50 meters using a 40mm M203 grenade launcher will take place combining less than lethal and dye marking capability upon impact with target personnel. This munition will immobilize personnel while clandestinely marking them for subsequent identification. **Supports:** Dismounted Battlespace Battle Lab (DBBL) and Early Entry Lethality and Survivability Battle Lab (EELS).

12 Gauge Round Technology Demonstration (96-98). Dispensed from a 12 gauge shotgun, numerous rounds exist which will be demonstrated. They include a *Rubber Pellet Round*, the *Single Ball Round*, and the *Bean Bag Round*. The *Rubber Pellet Round* is effective in crowd control situations where chemical munitions cannot be utilized. It is effective against individually selected targets or small groups who are not in possession of a firearm and who demonstrate violence or aggression against responding soldiers. The *Single Ball Round* consists of a single rubber ball, expelled down range toward the target and is intended to be used as a skip-fire munition. This single projectile could be used in crowd control situations and special arrests of violent suspects who are not in possession of a firearm. The *Bean Bag Round* is a bean bag projectile which is launched down range to the target and is intended to be direct fired. It is effective against individually selected targets or subjects who are not in possession of a firearm and who demonstrate violence or aggression. These weapons could be utilized by dismounted combat soldiers and the U.S. Army Military Police School (USAMPS). **Supports:** USAMPS, DBBL and EELS Battle Labs, dual use (law enforcement) applications.

Electric Water Cannon Technology Demonstration (94-97). The objective is to build and successfully demonstrate the non-lethal capability of electric water cannon devices which can be manportable or vehicle mounted. The device has been demonstrated at ranges out to 18 feet. The environmentally safe chemical additive for increasing laminar flow has been selected. The device would be effective for personnel immobilization and crowd control as well as in setting up a barrier or barricade. A threatening visible arc can be created to increase the deterrent value of this device. **Supports:** USAMPS, DBBL and EELS Battle labs, dual use (law enforcement) applications.

Mid-Sized Riot Control Dispenser Technology Demonstration (95-97). The USAMPS identified the need for a mid-sized riot control dispenser to fill the size gap between the existing, large M33A1 and the hand-held M36 dispersers. The mid-sized disperser will complement rather than replace these type classified dispersers. Objectives of the program will be to optimize nozzle design, payload capacity, and pressurizing to achieve the range, operation time, and weight of the system per the USAMPS requirements. **Supports:** USAMPS, DBBL and EELS Battle Labs.

Non-Lethal Entanglement Technology Demonstration (95-98). The purpose is to provide a less than lethal entanglement (and perhaps stun) capability for the 40mm M203 Grenade Launcher, while simultaneously retaining "standby" lethal capability of the M16 Rifle. Basic entanglement munition concept has applications to other large caliber and self-protection systems, and can be fielded in simple net, sticky net, or sting-net configurations. This projectile's effective range is 0 to 30 meters against personnel. **Supports:** USAMPS, DBBL and EELS Battle Labs, dual use (law enforcement) applications.

Electric Vehicle Stopper Technology Demonstration (94-97). The goal of the Electric Vehicle Stopper is to selectively stop moving vehicles at a distance while minimizing injuries to occupants and bystanders. This stopper is an emplaced device which can be remotely activated. Coupling mechanisms and triggering have been investigated. The effects of various waveforms for different vehicles is ongoing research. **Supports:** DBBL and EELS Battle Labs, USAMPS, dual use (law enforcement) applications.

Combustion Engine Defeat Mechanism Technology Demonstration (96-98). This TD demonstrates the feasibility of using a missile as a platform to deliver non-toxic, environmentally friendly, less-than-lethal agents to obstruct the filters of air-breathing mechanisms resulting in operational failure of the mechanism. This device would allow for reuse of the engine after replacing the filters. A scaled demonstration of the mechanism shutdown was successful without damage to the internal parts of the mechanism. Static tests with actual warheads and representative threat targets will be used to fully determine the feasibility of dispensing the agent and detecting the target within operational parameters followed by actual flight tests to check out the concept. This warhead could be integrated into most missile systems, unmanned aerial vehicles, and unmanned ground vehicles, limited only by targets of interest and engagement rates. This defeat mechanism will provide special operations forces with multiple low-intensity conflict/peacekeeping capabilities as well as dual-purpose options to support law enforcement. **Supports:** Current and future missile systems, EELS and DBBL Battle Labs, OOTW.

I.

Soldier Systems

Our warfighting edge is the combined effect of quality people, trained to razor sharpness, outfitted with modern equipment, led by tough competent leaders, structured into appropriate forces and employed according to up-to-date doctrine. . .I am certain the most important factor is the soldier.

General Gordon Sullivan
Army Chief of Staff

1. Introduction

The Army soldier modernization effort is a comprehensive, multifaceted program designed to maximize the operational capabilities of the soldier as a "battlefield system" capable of executing a full range of military operations by enhancing command and control, lethality, survivability, sustainability, and mobility. The Soldier System is generically defined as the individual soldier and everything he/she wears, consumes, or carries for individual use in a tactical environment. The merit of the systems approach to modernizing the soldier was successfully demonstrated in the Soldier Integrated Protective Ensemble (SIPE) Advanced Technology Demonstration (ATD), completed in December 1992. SIPE demonstrated the enhanced capabilities that could be achieved through a modular, integrated fighting system for the dismounted soldier. Two soldier system programs were initiated in its wake. The Land Warrior Engineering and Manufacturing Development (LW EMD) acquisition program was structured to maximize currently existing/mature technologies to field a system to meet the near-term soldier requirements. The Generation II Soldier Advanced Technology Demonstration (GEN II ATD) was established to demonstrate an advanced system and to integrate all the components of the 21st Century Land Warrior (21CLW) Science and Technology program.

At the conclusion of Phase II of the GEN II program, the Army consolidated its dismounted warrior programs (GEN II ATD and LW EMD). 21CLW/GEN II ATD was restructured and renamed Force XXI Land Warrior (FXXI LW). The FXXI LW 6.3 Science and Technology program is complementary to the U.S. Army's Land Warrior EMD Program being managed by PM Soldier. FXXI LW is also directly linked to and coordinated with Combat Identification (CID), Personnel Status Monitor (PSM), Lightweight Chemical Agent Detector (LWCAD), Integrated Sight (IS), Javelin, and the Objective Individual Combat Weapon (OICW). The technologies and capabilities being developed for the dismounted soldier in FXXI LW have broad application in other areas delineated in Chapter III, and represent opportunities for horizontal integration into other systems.

2. Relationship to Operational Capabilities

The five major Soldier Systems operational capabilities are: Command and Control (C2), Lethality, Survivability, Sustainability, and Mobility.

Command and Control is the soldier's ability to direct, coordinate, and control personnel, weapons, equipment, information, and procedures necessary to accomplish the mission. Command, control, and communications combined arms compatible systems provide total situational awareness from the aggregated capabilities of the soldier's radio and computer (using the Army's emerging architecture), integrated with digital head-mounted displays, combat ID, and navigation aids. Improvements will focus on individual communications, computer control systems, position navigation, information fusing and management, visual and aural enhancement (including image capture and transmission), and situational enhancement.

Lethality is the soldier's ability to detect, recognize, and destroy the enemy targets. Lethality systems will enhance individual, crew, and personal combat weapons with improved effectiveness. The Objective Individual Combat Weapon (OICW) ATD is the lethality component of the Soldier System and will provide the capability to attack defilade, non-line-of-sight targets and targets that have gone to ground. The LW capabilities will provide accurate, rapid, automated target handover to indirect fire support, enhancing the lethality of the total force.

Survivability is the ability to protect oneself against weapons effects and environmental conditions. The number one requirement for survivability is a "capability to place accurate fire on the enemy without exposing himself to fire," which will be accomplished through the integration of the OICW fire control and the LW system. Survivability systems will integrate multiple threat protection against ballistic, flame/thermal, chemical/biological, directed energy, surveillance, and environmental hazards. Combat identification capabilities will be integrated into soldier systems to minimize fratricide. Exploitation of the digital net, coupled with inherent enhancements, will significantly improve the survivability of the individual soldier and the entire force through increased controlled dispersion and a common picture of the battlefield.

Sustainability is the ability to maintain the force in a tactical environment. Sustainability systems will be adaptable to all levels of operations on the dynamic battlefield. Features include advanced A-ration quality field rations, nutritional tailoring to enhance physical and mental performance, a capability to eat on the move, individual purification of all water sources, and improvements in field feeding and field services. Sustainability also includes individual soldier power sources for low power draw tactical system components (e.g., computer/radio, helmet system, fire control).

Mobility is the ability to move about the battlefield with accompanying load to execute assigned missions. In the far term, it is envisioned that combat load handling devices will be employed to reduce the combat load of the dismounted soldier. Future mobility systems will allow accurate rapid air insertion for personnel, supplies, and equipment from ultra-high to very low altitudes at maximum airspeeds. Enhancing dismounted operations in snow and ice and at night will also be addressed. Advanced mobility sensors, coupled with the navigational aids (e.g., GPS, digital maps/overlays), greatly enhance the speed and accuracy of nighttime maneuverability of the individual and unit.

The Army's soldier modernization strategy calls for the demonstration, development, and integration of a series of Systems and System Upgrades (S/SUs). Soldier S/SUs have their greatest impact in the functional areas of Dismounted Battlespace, Battle Command, Combat Service Support, and Early Entry. New operational capabilities that will be afforded in each of these functional areas are listed in Table III-I-1.

3. Soldier Systems Modernization Strategy

The goal of soldier systems modernization is to develop a fully integrated modular system which will allow the Army to field multiple configurations by tailoring software and hardware for specific unit missions and locations on the battlefield. Modularity will allow Commanders and individual soldiers to better perform their missions by carrying only the required components, consistent with Mission, Enemy, Troops, Terrain, and Time (METT-T).

To support planned materiel development programs for the Soldier, the Army's Science and Technology (S&T) community continues to explore and demonstrate a full range of state-of-the-art technologies. This will maximize the soldier's battlefield capabilities as expressed in the Soldier Annex to the Army Modernization Plan.

The FXXI LW system is operationally focused on the U.S. Army Infantry, the U.S. Marine Corps (Infantry), and the U.S. Special Operations Forces. It will be the link into the digitized force of the future using the Army's emerging technical architecture. The result will be enhanced survivability, situational awareness, and lethality at both the individual and unit level. Advanced technologies in microelectronics, weaponry, and protection will be systematically applied to the individual soldier, marine, and special operators to augment their operational capabilities to achieve maximum synergy between human and equipment performance.

4. Soldier Systems Modernization Roadmap

Table III-I-2 presents the demonstrations and systems which are part of the Soldier Systems Modernization Roadmap (see Figure III-I-1).

Table III-I-1. Soldier Systems Modernization System Capabilities

S/SU FUNCTION	BATTLEFIELD DYNAMICS: Early Entry	Depth and Simultaneous Attack	Mounted Battlespace	Dismounted Battlespace	Battle Command	Combat Service Support	SYSTEM/SYSTEM UPGRADE CAPABILITIES	ADVANCED CONCEPT CAPABILITIES
LETHALITY								
System								
Obj. Family of Small Arms	●		○	●	●	○	• Laser marker, 300m viewing range • Interface to Mini Eye-Safe Laser IR Observation Set (MELIOS) • Thermal weapon sight (TWS), 550m range to detect man-sized targets • Increased accuracy, Ph, and range • Lightweight system	
Obj. Sniper Weapon	●	○	○	●	○	○		
System Upgrade								
Objective Individual Combat Weapon (OICW)/Objective Crew Served Weapon (OCSW)	●	○	○	●	○	○	• Increased Ph and Pi • FLIR integrated with laser rangefinder, compass, aim light, and ID interrogator • 1000m viewing range for aim light • Full solution fire control/ballistic computer • Increased range and effectiveness of munitions • Decisive violent target effects • High hit probability • Lightweight two-man weapons • Immediate incapacitation	
COMMAND AND CONTROL								
System Upgrade								
Land Warrior	●		○	●	●	○	• Computer/soldier radio system with GPS (5 lb) • Computer/secure squad radio/ soldier radio system with hand-held flat panel display and GPS (7 lb) • Monochrome HMD • GPS locator • Color overlays and maps on palm top display • Automated reporting software • Interactive embedded training • Video capture and transfer (single frame) • NBC monitoring • Integrated high capacity tactical computer with extended range radio (≈2-3 lb) • High resolution flat panel HMD • SINCGARS SIP gateway to higher echelons (e.g., CAC2) at platoon • GPS plus self-contained navigation • Computer input by voice or "free screen" • Color video capture and transfer (single frame plus modom) • Automated medical and NBC monitoring • Immediate incapacitation	
SURVIVABILITY								
System								
Land Warrior	●		○	●	●	○	• HMD (fire weapon without self exposing) • Improved Chem/Bio clothing • Body armor • Laser detector • Specs/BLEPS	
SUSTAINABILITY								
System Upgrades								
Army Field Feeding Future	●		○	●	●	○	• Lightweight, low volume, shelf stable rations • Optimized acceptance/consumption • Improved operational flexibility • Performance enhancer	

● Provides Significant Capability ○ Provides Some Capability

Table III-I-2. Soldier Systems Demonstration and System Summary

ATDs	TECHNOLOGY DEMONSTRATIONS
• Objective Individual Combat Weapon (OICW) **ACTDs** • Military Operations in Urban Terrain (For additional information, see Vol. II, Annex B.)	• Force XXI Land Warrior (FXXI LW) • Multipurpose Individual Munition/Predator • Objective Crew Served Weapon (OCSW) • Integrated Sight • High Heat Food Stabilization • Objective Personal Weapon (OPW) • Objective Sniper Weapon • Performance Enhancing Demos
SYSTEMS/SYSTEM UPGRADES/ADVANCED CONCEPTS	
Systems Land Warrior (EMD and FXXI LW S&T) Objective Family of Small Arms Objective Sniper Weapon	***System Upgrades*** Army Field Feeding Future OICW, OCSW

a. Command and Control Demonstrations

Force XXI Land Warrior (FXXI LW) (96-98). The primary objectives of FXXI LW are to pursue:

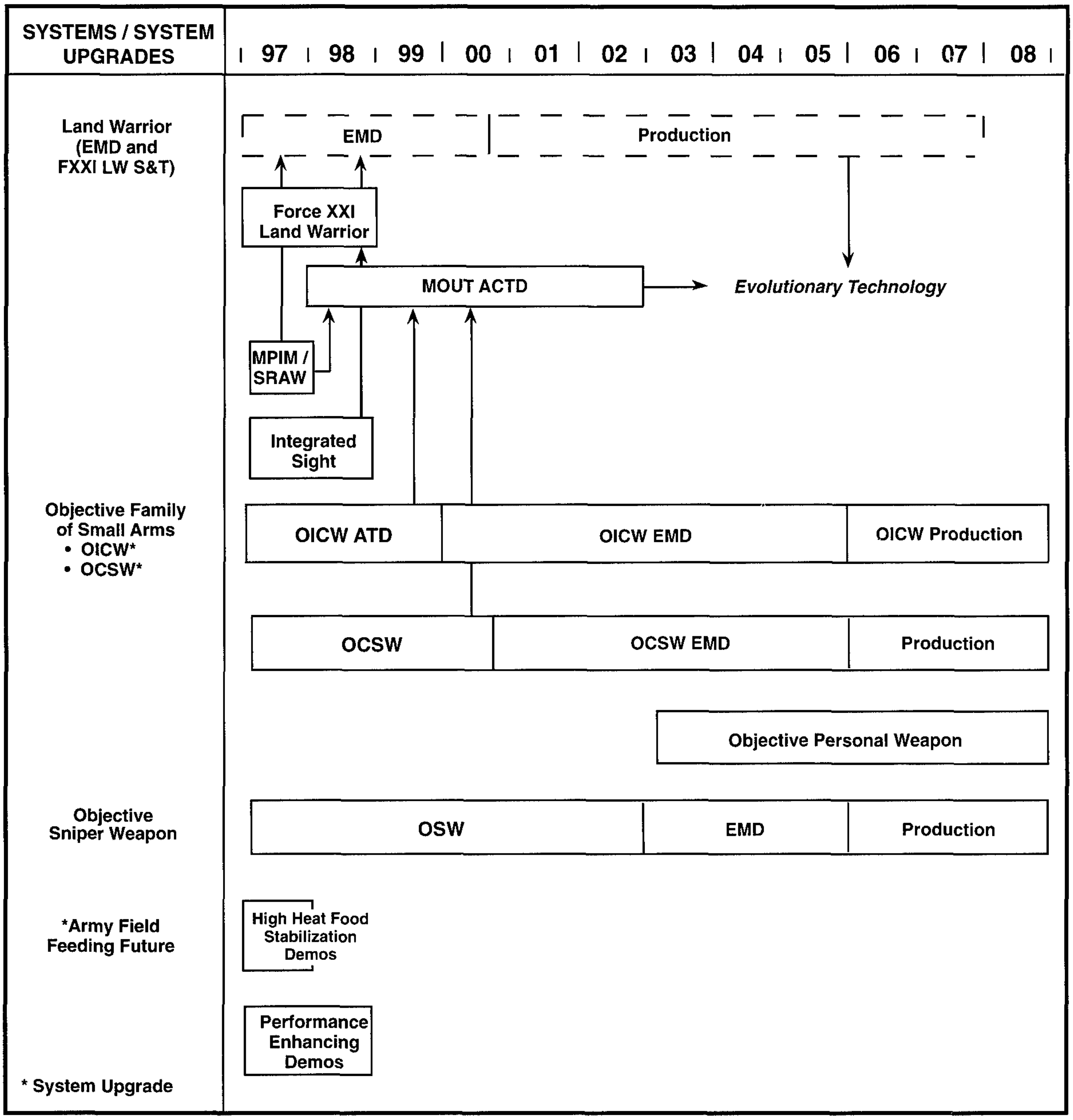
- Evolutionary advanced technology developments at the component level and integration of those technology upgrades into the LW EMD system architecture to support an Early User Test (EUT).
- Revolutionary advanced technology developments that would provide more far-reaching enhancements to the LW System.
- Technology efforts to help reduce the risks associated with reaching the LW EMD Milestone III on schedule.

Specific technologies to be pursued include lighter weight helmet materials and designs, modeling and simulation, wireless weapon and sensor interfaces, integrated sight, enhanced navigation, packet relay protocols for soldier radio, system voice control, combat ID functions, helmet-mounted display upgrades (1280x1024, and low power 640x480), handheld color displays, and head orientation sensor. In addition to these technologies, integration of PSM and LWCAD components onto the LW platform will also be accomplished. Future upgrades to the LW system will include electronically coupled indirect night vision, digital image processing, optimized computer architecture concepts, and interfaces to future infantry systems such as the Objective Individual Combat Weapon (OICW).

FXXI LW will perform risk reduction efforts to assist in fielding the LW EMD System on schedule. These efforts include pursuing lighter weight helmet materials, design, and integration variations to reduce weight and optimize CG; utilizing rapid prototyping and load assessment capabilities; and leveraging Modular Body Armor/Load Bearing Programs. Modeling and simulation will be used to evaluate FXXI LW performance characteristics such as survivability and lethality. Constructive system modeling, virtual simulation, and other tools will be used to examine the contribution of FXXI LW capabilities to future military organizations engaged in force-on-force combat engagements. This program will make extensive use of Integrated Product and Process Development (IPPD) to ensure that critical manufacturing processes are developed in parallel to the design of the technical components. This approach will ensure a viable, affordable, and producible product which will perform as expected in the field.

A two-phase EUT will assess the viability of the evolutionary enhancements that are integrated into Pre-production Qualification Test (PPQT) LW EMD Systems. The EUT evaluation, conducted at the squad level, will be a field test utilizing Land Warrior systems configured with FXXI LW evolutionary insertion candidates and available revolutionary operational enhancements. This strategy will accelerate the fielding of technology upgrades and ensure the U.S. maintains a global technology overmatch for dismounted warrior combat systems.

Figure III-I-1. Roadmap for Soldier Systems Modernization



b. Lethality Demonstrations

The lethality demonstrations will focus on weapons, munitions, and target detection and acquisition.

Objective Individual Combat Weapon (OICW) ATD (94-99). The OICW, as defined in the Joint Service Small Arms Master Plan (JSSAMP) and the approved Mission Need Statement (MNS), is the next generation "individual" weapon envisioned to replace some of the current inventory of small arms weapon systems. Two OICW concepts are being developed by competing contractor teams. Both concepts include kinetic energy (5.56 mm) and airburst (20 mm) munitions. A significant new capability afforded by OICW will be the ability to defeat targets in defilade using bursting munitions. This ATD will demonstrate the potential of the OICW to provide an overmatch against threat infantry soldiers, as required in the JSSAMP. It will involve realistic operational assessments with troops and key on the soldier's ability to acquire and defeat targets. The performance potential of the OICW will be assessed against the baseline M16A2/M203 and the modular weapon. Measures of effectiveness include probability of hit, probability of incapacitation, kills per combat load, and cost per kill. The significant potential of the OICW in an urban environment will be demonstrated in the Military Operations in Urban Terrain (MOUT) ACTD. The technologies exploited to achieve the overmatch capability include high strength, ultralightweight materials, high tech miniaturized fuzing, high explosive air bursting projectiles, electronic ranging, ballistic computation, reticle displacement, video sighting and sophisticated fire control devices. **Supports:** OICW and MOUT ACTD.

Multipurpose Individual Munition/SRAW (MPIM/SRAW) Technology Demonstration (95-97). This effort provides for a technology demonstration of a lightweight, shoulder-fired, multiple purpose weapon. The objective of the demonstration is to integrate the MPIM warhead with the USMC SRAW system and demonstrate the capability to defeat a variety of targets while also being able to be safely fired from an enclosure. It will enhance soldier lethality by providing the infantry with one weapon capable of defeating enemy forces in buildings, bunkers, and lightly armored vehicles. The system will have tremendously increased lethality over the current shoulder-fired systems as well as being multiple target capable. System design will allow for growth, service life extension, and technology insertion to support the U.S. Army mission of crisis response to regionally based threat. Assessments will use MPIM/SRAW in appropriate scenarios (e.g., MOUT). **Supports:** MOUT ACTD.

The Objective Crew-Served Weapon (OCSW) Technology Demonstration (96-00). Part of the Objective Family of Small Arms, the OCSW demo will support the two-man, crew-served weapon outlined in the JSSAMP. This demonstration will establish the feasibility of a lightweight, two-man portable crew-served weapon system capable of defeating personnel and light vehicle targets to 2000 meters. This TD is discussed in further detail in Section H, *Close Combat Light*. **Supports:** MOUT ACTD.

Integrated Sight (IS) Technology Demonstration (94-98). The IS TD will develop and demonstrate optimum components and integration of a thermal imager, laser rangefinder, electronic compass, and near IR pointer into a compact sighting system. Imagery and data will be output to the LW HMD and soldier's computer. These technologies will provide the soldier with extended range and automated targeting capabilities. IS also supports advanced weapons, including the OICW and OCSW. **Supports:** Lightweight Laser Designator/Rangefinder (which incorporates IS technologies and/or components in their fire control).

c. Survivability Demonstrations

Force XXI Land Warrior (FXXI LW) (96-98). FXXI LW encompasses inherent survivability enhancements, as well as the integration of several survivability components. Inherent enhancements include advanced, lightweight body armor providing small arms and fragmentation protection in the ballistic helmet shell, and system signature reduction/control (e.g., visual, near IR, thermal, electronic). Other survivability enhancement components include the Personnel Status Monitor (DARPA) and the Lightweight Chemical Agent Detector. The Personnel Status Monitor consists of a suite of non-invasive biosensors linked to the LW computer/radio, providing the capability to rapidly prioritize and locate combat casualties (via the computer-embedded GPS and linkage to the digital net), as well as improving casualty care via access to the biomedical data saved in the computer/radio. The Lightweight Chemical Agent Detector will link to the LW computer/radio and helmet, delivering a warning to the soldier that a contaminated area had been entered. The linkage to the digital net will, in turn, provide a warning to higher echelons of the coordinates of the contaminated area to allow other units to avoid that area.

d. Other Soldier Systems Demonstrations

Military Operations in Urban Terrain (MOUT) ACTD (98-02). The MOUT ACTD is a joint (Army/Marine Corps) program that encompasses a breadth of technologies ranging from an advanced soldier system, advanced individual precision weapons, combat identification, counter-sniper, non-lethal weapons, advanced sensors, situational awareness, and personal protection. The core capability that will be generated via the ACTD is a linkage of a series of advanced systems/components into a MOUT "System of Systems" whereby the components are interfaced, integrated, or linked in an architecture to ensure their effective interoperability and functionality in the challenging MOUT environment. The integrated MOUT System of Systems will provide a robust and enhanced joint operational capability encompassing the areas of urban command, control, communication, computers, and intelligence (C4I); engagement; and force projection. **Supports:** Upgrades to Force XXI Land Warrior.

High Heat Food Stabilization Demonstrations (94-97). To enhance high heat stability and quality of individual rations, technology insertions are planned to include: reformulation using heat-tolerant ingredients; raising microviscosity by manipulating glass transition temperature to minimize deteriorative physical and chemical reactions, and improve nutrient bioavailability at high temperatures. State-of-the-art shelf-life indicators and rapid quantitative food quality prediction and assessment methods/kits are being developed to ensure that only high quality rations reach the individual soldier on the battlefield. **Supports:** Army Field Feeding Future.

Performance Enhancing Demonstrations (95-98). Special supplemental components containing performance enhancing ingredients will be developed and demonstrated to enhance performance under stressful conditions during sustained operations. These components will supplement the Individual Combat Ration to heighten alertness, extend endurance, and reduce the effects of high altitude sickness. **Supports:** Army Field Feeding Future.

Objective Personal Weapon (OPW) (04-09). The OPW is the side arm of the future. It will provide increased accuracy and incapacitation for close-in self-defense in last ditch combat situations, as well as some extended offensive capability in special operations, military police operations, and dignitary protection. The envisioned OPW will employ technically advanced, leap-ahead concepts, and technologies that span the entire electromagnetic spectrum, yielding incapacitating mechanisms of a non-conventional nature. It will be capable of immediate incapacitation (target ceases to remain a threat) out to 50 meters against personnel with body armor. It will have substantially increased accuracy, hit probability, and target effects. This lightweight system will not exceed 3 pounds and will be user friendly with hands-free carry. It will provide multiple engagement capability and be operational day or night, in all weather conditions, on land/sea/surf/air. **Supports:** Objective Family of Small Arms.

Objective Sniper Weapon (OSW) Technology Demonstration (97-02). The OSW is the single sniper weapon which will achieve the required future capabilities of the joint sniper communities, to include conventional military, special operations forces, and law enforcement. Its increased precision and range will enable the sniper to more effectively engage targets, human (protected or unprotected), and light materiel, out to 2,000 meters. It will have increased accuracy and hit probability. This lightweight system will be operational day or night; in all weather conditions; on land, sea, or air; and will weigh 10 to 15 pounds. **Supports:** Objective Sniper Weapon.

5. Relationship to Army Modernization Plan Annexes

The Soldier Systems S/SU linkages with other Army Modernization Plan Annexes are shown in Figure III-I-2.

Figure III-I-2. Correlation Between Soldier Systems S/SU/ACs and Other Army Modernization Plan Annexes

SOLDIER SYSTEMS/SYSTEM UPGRADES		Mounted Forces	Close Combat Light	Aviation	C4	Fire Support	Engineer & Mine Warfare	IEW	NBC	Combat Health Support	Training	Space
		MODERNIZATION PLAN ANNEXES										
Systems	Objective Family of Small Arms		●	O		O						
	Land Warrior (EMD and FXXI LW S&T)	O	●	O	●	●	O	●	●	O	●	O
	Objective Sniper Weapon	O	●			●						
System Upgrades	Army Field Feeding Future	O	O							O		O
	OICW		●									
	OCSW	O	●									

● System plays a significant role in the Modernization Strategy.

O System makes a contribution to the Modernization Strategy.

J. Combat Health Support

The mission of the Army Medical Department is to provide world class combat casualty care to America's most precious resource, its sons and daughters, in peace and war.

GEN Maxwell R. Thurman (Sept. 95)

1. Introduction

The major goals of the Army Combat Health Support (CHS) science and technology program are threefold: first, to prevent illness and injury; second, to sustain optimum military effectiveness; and, third, to treat casualties. The greatest payoff from the investment in CHS science and technology comes from the identification of medical countermeasures which eliminate health hazards. Preventive measures include biomedical technologies, information and materiel to protect the force from infectious disease, environmental injury, health hazards of combat systems, operational stress, and aggressor weapons (i.e., conventional, chemical, biological, or directed energy systems).

Medical research provides vaccines, pretreatment drugs, and training strategies which maximize the readiness of soldiers to deploy and fight. Medical research assists leaders in optimizing warfighting capabilities across the full continuum of conflict, from peacekeeping to high intensity combat. Medical research also provides the means to maximize far-forward diagnosis, treatment, and return-to-duty of combat casualties. Military-unique medical contributions include such items as field-deployable diagnostic kits, chemical and biological antidotes, resuscitative devices, blood preservatives, and enhanced medical evacuation platforms.

2. Relationship to Operational Capabilities

Key points in developing Combat Health Support are the scenario and METT-T (mission, enemy, terrain, troops available, and time), as well as the medical intelligence assessment of the battlefield, which includes threats to the health of the soldier. The level of confidence for success of the force during operations will be greater if the force is psychologically, physically, and nutritionally fit, protected from illness through a vigorous vaccination program, and sustained through state-of-the-art medical care as limited by the battlefield environment. As battle and non-battle health threats are reduced, casualties and force requirements will be reduced correspondingly. Fulfilling the vision of each of the Battle Labs will require significant input from the military medical S&T community. Examples of medical technologies impacting upon Army operations and the Battle Labs are: vaccines; pretreatments and treatments against biological and chemical threats; nutritional strategies; medical information products; environmental and behavioral performance models; improved capability for far-forward surgical stabilization of combat casualties; enhanced ground and aeromedical evacuation; and medical telepresence technologies.

Combat Health Support modernization operational capabilities supporting Early Entry, Mounted and Dismounted Battlespace, and Combat Service Support appear on Table III-J-1.

3. Combat Health Support Modernization Strategy

Modernization efforts focus on the development of medical materiel, through a DoD drug and vaccine program, for countering potential mission aborting infectious diseases as well as chemical and biological warfare agents. Such drugs and vaccines are not normally developed by the U.S. pharmaceutical industry. Additional capabilities of the medical program include technologies supporting far-forward casualty treatment; individual sustainment (self aid devices and techniques) to reduce the severity of ballistic, thermal, and directed energy injuries; topical skin protectants; blood substitutes; and miniature and filmless x-rays. The modernization strategy also addresses nutritional and physiological approaches to minimize the impact of military operational stresses which degrade the capabilities of, or render inoperable, the human component of combat systems.

Table III-J-1. Combat Health Support Modernization System Capabilities

S/SU/AC FUNCTION	Early Entry	Depth and Simultaneous Attack	Mounted Battlespace	Dismounted Battlespace	Battle Command	Combat Service Support	SYSTEM/SYSTEM UPGRADE CAPABILITIES	ADVANCED CONCEPT CAPABILITIES
MEDICAL DEFENSE AGAINST INFECTIOUS DISEASE								
Systems/System Upgrades	●	○	●	●	○	●	• Vaccine against blood and tissue stages of malaria • Antimalaria drug for drug-resistant malarias • Vaccine against Campylobactor • Vaccine for hemorrhagic fevers • Topical insect repellent	• E. Coli-Shigella sonnei hybrid vaccine • Paromomycin topical anti-leishmanial drug • Artemisinin antimalaria drug • Live attenuated Dengue vaccine • Vaccine against HIV
Advanced Concepts	●	○	●	●	○	●		
MEDICAL BIOLOGICAL DEFENSE								
Systems/System Upgrades	●	○	●	●	○	●	• Ricin subunit vaccine • Encephalomyelitis vaccines • Botulinum toxoid • Staphylococcal Enterotoxin B (SEB) toxoid • Rapid identification/diagnosis kit	• Definitive diagnostic capabilities • Immunization against biological threat agents • Multiagent vaccine against biological threat agents • Pretreatment against biological threat agents
Advanced Concepts	●	○	●	●	○	●		
MEDICAL CHEMICAL DEFENSE								
Systems/System Upgrades	●	○	●	●	○	●	• Field diagnostic test kit, nerve agent exposure • Improved chemical casualty management system • Cyanide pretreatment • Topical skin protectant • Nerve agent multichambered autoinjector	• Biologically active countermeasure for chemical warfare agents • Advanced skin/wound decontamination system • Vesicant and respiratory agent therapy • Advanced anticonvulsant • Reactive topical skin protectant
Advanced Concepts	●	○	●	●	○	●		
COMBAT CASUALTY CARE								
Systems/System Upgrades	●	○	●	●	○	●	• Low volume resuscitation solutions • Tissue adhesives for hemorrhage control • Bone marrow infusion device • Thawed blood storage solution • Microencapsulated antibiotics • Upgrade evacuation platform, enhanced in-route care, and field anesthesia machine	• Microwave warmer for resuscitation fluid and blood • Drugs to prevent immunosuppression and sepsis • Medical diagnostics and communications for casualty care • Hibernation drug • Cell/organ preservation drug • Hemorrhage control agents and devices
Advanced Concepts	●	○	●	●	○	●		
ARMY OPERATIONAL MEDICINE								
Systems/System Upgrades	●	●	●	●	●	●	• Reduction and prevention of operational stress • Paratrooper ankle brace • Anti-endotoxin antibody for heat stroke treatment • Nutritional supplements	• Vision-corrective eyewear integrated with headgear • Performance enhancement via nutrition • Sleep and alertness enhancement
Advanced Concepts	●	●	●	●	●	●		

The six capability columns are grouped under the heading BATTLEFIELD DYNAMICS.

● Provides Significant Capability ○ Provides Some Capability

4. Combat Health Support Modernization Roadmap

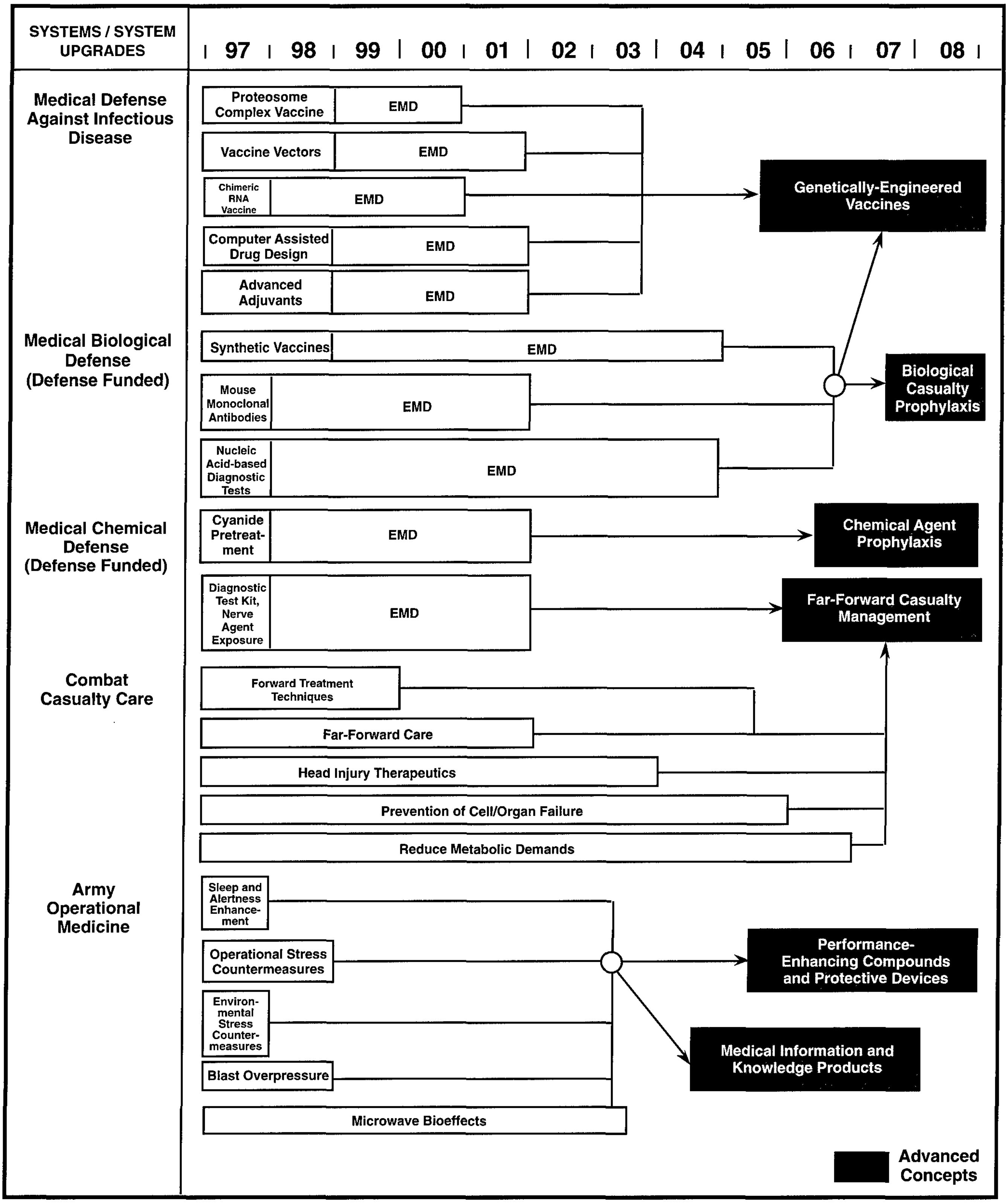
Table III-J-2 presents a summary of demonstrations and systems listed in the Combat Health Support Modernization Roadmap (Figure III-J-1). Army medical S&T programs support a diversity of non-materiel advanced development technology demonstrations (TDs). Unlike most non-medical TDs, medical TDs must be conducted in a laboratory, rather than in the field environment, because of the regulatory requirements placed on medical materiel by the U.S. Food and Drug Administration (FDA).

The FDA requires that a medical product (e.g., vaccine, medical device, or drug) have demonstrated preclinical safety and efficacy prior to the product's evaluation in man. Thus the medical system acquisition process has led to a tailored Life Cycle System Management Model for medical materiel. It is in the TD phase of the medical materiel life cycle that technology candidates are fully evaluated for pre-clinical (prior to human use) safety and efficacy. The best candidates are then selected for transition. Descriptions of major technology demonstrations are provided on the following pages. Dates provided in the text reflect the timeline of the product from technology base research to development (Medical Milestone I).

Table III-J-2. Combat Health Support Demonstration and System Summary

ATDs	TECHNOLOGY DEMONSTRATIONS
Although there are currently no Army Medical ATDs, the DoD Drug and Vaccine Program, for which the Army is the Lead Agent, is an ATD equivalent.	**Medical Defense Against Infectious Disease** • Vaccine Vectors • Proteosome Complex Vaccines • Chimeric RNA Vaccines • Computer Assisted Drug Design • Advanced Adjuvants **Medical Biological Defense** • Synthetic Vaccines • Mouse Monoclonal Antibodies • Nucleic-acid Diagnostic Tests **Medical Chemical Defense** • Field Diagnostic Test Kit, Nerve Agent Exposure • Cyanide Pretreatment **Combat Casualty Care** • Prevention of Cell/Organ Failure • Reduce Metabolic Demands • Far Forward Care • Forward Treatment Techniques • Head Injury Therapeutic Technology **Army Operational Medicine** • Sleep and Alertness Enhancement • Operational Stress Countermeasures • Blast Overpressure • Microwave Bioeffects • Environmental Stress Countermeasures
SYSTEMS/SYSTEM UPGRADES/ADVANCED CONCEPTS	
Systems/System Upgrades • Medical Defense Against Infectious Disease • Medical Biological Defense • Medical Chemical Defense • Combat Casualty Care • Army Operational Medicine	***Advanced Concepts*** • Genetically Engineered Vaccines • Biological Casualty Prophylaxis • Chemical Agent Prophylaxis • Far Forward Casualty Management • Performance Enhancing Compounds and Protective Devices • Medical Information and Knowledge Products

Figure III-J-1. Roadmap for Combat Health Support Modernization



a. Demonstrations Supporting System of Medical Defense Against Infectious Disease

Successful development of a vaccine for malaria, bacterial diarrhea, insect-borne viruses, or human-immunodeficiency virus depends on innovative methodology. Several genetic engineering technologies are being used to develop new vaccines that can be given orally; provide long-lasting protection with fewer doses; or protect the soldier from multiple diseases with a single product.

Vaccine Vectors (89-98). Mutant auxotrophic vectors are live bacteria which have a limited ability to reproduce within man. Presentation of the vaccine by live bacteria markedly enhances the effectiveness of the vaccine, while the use of auxotrophic bacteria as carriers limits the period of infection and thus improves the safety of the vaccine. **Supports:** Genetically-Engineered Vaccines.

Proteosome Complex Vaccines (90-98). The use of antigens encapsulated in protein structures called proteosomes leads to a markedly increased recognition of the antigen by the body's immune system. This results in a more highly effective vaccine. **Supports:** Genetically-Engineered Vaccines.

Chimeric RNA Vaccines (87-97). Introducing the genetic material from disease producing bacteria into innocuous bacteria produces a chimeric organism incapable of producing disease by itself. However, the organism can produce the antigens of the pathogen which will safely induce protective immunity in man. **Supports:** Genetically-Engineered Vaccines.

Computer-Assisted Drug Design (95-98). Determination of the three-dimensional structure of drug and vaccine target molecules will allow the design of specific complementary drugs and vaccines which will inhibit the function of key biological processes in infectious organisms, providing immunity to infection or novel drugs for treating disease. **Supports:** Genetically-Engineered Vaccines.

Advanced Adjuvants (95-98). Coupling vaccine components to certain stimulatory molecules results in a substantial increase in the immune system's response to vaccination. **Supports:** Genetically-Engineered Vaccines.

b. Demonstrations Supporting System of Medical Biological Defense (Defense Funded)

Synthetic Vaccines (93-98). This will develop vaccines utilizing an artificial process to produce a product which mimics a natural antigen. This will result in vaccines that are safer and cheaper to produce, and safer to use as vaccines. **Supports:** Biological Casualty Prophylaxis.

Mouse Monoclonal Antibodies (93-97). This demonstration allows for production of sensitive and specific reagents for diagnosis of service members exposed to biological threat agents. **Supports:** Biological Casualty Prophylaxis.

Nucleic-Acid Diagnostic Tests (95-97). Extremely sensitive DNA/RNA amplification techniques are being configured on microchip, probes, and membrane read-out systems. This will provide rapid, sensitive, and specific confirmation of select biological threat agents in clinical materials. **Supports:** Biological Casualty Prophylaxis.

c. Demonstrations Supporting System of Medical Chemical Defense (Defense Funded)

Cyanide Pretreatment (94-97). A methemoglobin former will be used as an oral pretreatment to protect soldiers against battlefield levels of cyanide. Methemoglobin preferentially binds cyanide, removing it from the toxic active site, thereby restoring normal cellular respiration. The lead candidate compound is an 8-aminoquinoline which is undergoing evaluation for safety and efficacy. **Supports:** Chemical Agent Prophylaxis.

Diagnostic Field Test Kit, Nerve Agent Exposure (95-97). This field test kit will measure cholinesterase for the diagnosis of moderate exposure to organophosphate nerve agents. This kit, which uses the hemoglobin-adjusted red blood cell acetylcholinesterase test method, will offer high test reliability and ease of use in field settings, and will significantly enhance diagnosis, screening, and epidemiology of nerve agent exposure. **Supports:** Far-Forward Casualty Management.

d. Demonstrations Supporting System of Combat Casualty Care

Forward Treatment Techniques (93-99). This demonstration will provide biologics and forward treatment intervention regimens for the prevention of brain/spinal damage, immunosuppression, sepsis, and general organ failure following shock and other major battlefield trauma. **Supports:** Far-Forward Casualty Management.

Far-Forward Care (93-01). This demonstration will enhance forward battlefield capability to resuscitate following hemorrhage, integrate physiologic monitoring and other life support equipment, and provide expert consultative systems for diagnosis, triage, and treatment of combat casualties. **Supports:** Far-Forward Casualty Management.

Head Injury Therapeutic Technology (93-03). This demonstration will show feasibility of therapeutic measures which reduce the effects of trauma to the brain and central nervous system, thus reducing a major source of battlefield mortality. **Supports:** Far-Forward Casualty Management.

Prevention of Cell/Organ Failure (93-05). This demonstration will provide biologics/pharmaceuticals for use far-forward in the treatment of massive trauma. These compounds will preserve cellular function and integrity, and reduce cell and tissue death following injury. Reductions in cellular death will help reduce battlefield mortality when combined with other, state-of-the-art techniques for combat casualty care. **Supports:** Far-Forward Casualty Management.

Reduce Metabolic Demands (93-06). This demonstration will provide pharmaceutical biologics which reduce the body's metabolic demand, and attempt to match metabolic oxygen demand to the current ability to supply oxygen to the tissues. In this way, cells will not starve for oxygen, and will not subsequently release toxic metabolic by-products. Reductions in metabolism demand will help reduce battlefield mortality when combined with other state-of-the-art techniques for combat casualty care. **Supports:** Far-Forward Casualty Management.

e. Demonstrations Supporting System of Army Operational Medicine

Sleep and Alertness Enhancement (92-97). This will demonstrate the efficacy of pharmacologic and behavioral interventions to counteract the effects of inadequate restorative sleep and to enhance soldier vigilance and performance during sustained and continuous operations. New compounds to induce sleep and to enhance restorative value of sleep; new measurement tools as rapid, reliable, and inexpensive means for assessing a soldier's level of mental fatigue and alertness; and improved guidance for individual and unit performance as a function of sleep and work/rest cycles, all designed to increase soldier effectiveness, will be evaluated and transitioned. **Supports:** Performance Enhancing Compounds and Protective Devices, Medical Information and Knowledge Products.

Operational Stress Countermeasures (92-98). This will demonstrate the efficacy of behavioral and materiel countermeasures to sustain performance during combat and OOTW. Improved unit effectiveness and decreased incidence of combat stress casualties as a result of proactive management of operational stress will be demonstrated. Behavioral, nutritional, and pharmacological methods for reducing the emotional, physical, and intellectual stress associated with extended periods of hypervigilance, crisis management, sleep debt, undernourishment, and strenuous exercise will be validated, as well as improved methods for far-forward management of combat stress casualties. **Supports:** Performance Enhancing Compounds and Protective Devices, Medical Information and Knowledge Products.

Environmental Stress Countermeasures (92-97). This will demonstrate the reliability and utility of models to predict performance degradation and casualties caused by exposure to extreme climates (heat, cold, and high terrestrial altitude). Models will be transitioned into operational guidance which will assist small unit leaders in planning training and military operations. **Supports:** Performance Enhancing Compounds and Protective Devices, Medical Information and Knowledge Products.

Blast Overpressure (92-98). This will demonstrate the reliability and utility of improved medical criteria for operator exposure to military weapons systems which create blast overpressure. Models will expand to include specific hazards for military women. Predictive models for incorporation into design standards for military systems which protect soldiers and maximize system performance will be transitioned. **Supports:** Performance Enhancing Compounds and Protective Devices, Medical Information and Knowledge Products.

Microwave Bioeffects (92-02). This will demonstrate the reliability and utility of models to predict performance degradation and injuries caused by exposure to military systems which produce electromagnetic radiation. Models will expand to include specific hazards for military women. Predictive models for incorporation into design standards for military systems which protect soldiers and maximize system performance will be transitioned. Operational guidance will also be developed which will assist commanders in planning training and military operations. **Supports:** Performance Enhancing Compounds and Protective Devices, Medical Information and Knowledge Products.

5. Relationship to Modernization Plan Annexes

To support the Combat Health Support Modernization Annex of the Army Modernization Plan, new generations of medical systems and products will be tested for technical feasibility and operational utility. Primary emphasis will be placed on capabilities to minimize casualties through improved protection and prevention as well as reduce treatment time for soldiers incapacitated by disease or injury. The relationship between the Combat Health Support systems and other Army Modernization Plan Annexes is shown in Figure III-J-2.

Figure III-J-2. Correlation Between Combat Health Support S/SU/ACs and Other Army Modernization Plan Annexes

COMBAT HEALTH SUPPORT SYSTEMS/SYSTEM UPGRADES/ADVANCED CONCEPTS		MODERNIZATION PLAN ANNEXES							
		Mounted Forces	Close Combat Light	Aviation	C4	Fire Support	Soldier Systems	NBC	Logistics
Systems/ System Upgrades	Medical Defense Against Infectious Disease	○	○	○	○	○	●	○	●
	Medical Biological Defense	○	○	○	○	○	●	●	○
	Medical Chemical Defense	○	○	○	○	○	●	●	○
	Army Operational Medicine	○	●	●	○	○	●	○	○
	Combat Casualty Care	○	○	○	○	○	●	○	●
Advanced Concepts	Genetically Engineered Vaccines	○	○	○	○	○	●	○	○
	Biological Casualty Prophylaxis	○	○	○	○	○	●	●	○
	Chemical Agent Prophylaxis	○	○	○	○	○	●	●	○
	Far-Forward Casualty Management	○	○	○	○	○	●	○	○
	Performance Enhancing Compounds and Protective Devices	○	●	●	○	○	●	○	○
	Medical Information and Knowledge Products	○	○	●	○	○	●	○	○

● System plays a significant role in the Modernization Strategy.

○ System makes a contribution to the Modernization Strategy.

K. Nuclear, Biological, Chemical (NBC)

(Defense Funded)

The proliferation of these horrific weapons presents a grave and urgent risk to the United States and our citizens, allies, and troops abroad. Reducing this risk is an absolute priority of the United States.

Pentagon Threat Assessment, "Proliferation: Threat and Response," April 11, 1996

1. Introduction

Joint Service Program

In response to congressional interest in the readiness and effectiveness of U.S. NBC warfare defenses, Title XVII of the National Defense Authorization Act for Fiscal Year 1994 (Public Law 103-160) required the Department of Defense to consolidate management and oversight of the Chemical and Biological (CB) Warfare Defense program into a single office within the Office of the Secretary of Defense (OSD) and to execute oversight of the program through the Defense Acquisition Board process. The public law also designated the Army as the Executive Agent for coordination and integration of the program, and consolidates NBC warfare defense training activities at the U.S. Army Chemical School. In addition, all Services' funding requests are now combined into a single program element for each of the funding categories (research, development, test, and evaluation, etc.). This process consolidates individual Service requirements and development efforts into a true joint program of common requirements, research, and development efforts.

The NBC section of the Army Science and Technology Master Plan reflects a joint Service technology base strategy for CB defense. The strategy herein is consistent with the Army Modernization Plan, the Joint Service NBC Modernization Plan, the Joint Service NBC Defense RDA Plan, and the DoD Chemical Biological Defense Technology Area Plan. The Army program in Smoke/Obscurants and Target Defeating Technologies (flame incendiary, antimaterial, riot control) is not a part of the joint CB Defense Program, but is included as a traditional part of the Army NBC defense mission area.

NBC Mission Area

Any nation with the will and the necessary resources can develop a formidable offensive nuclear, biological, and chemical warfare capability. They can readily turn their legitimate nuclear, medical, biotechnology, and chemical facilities to the development of NBC weapons. Additionally, the sale of technology and loss of control over Weapons of Mass Destruction (WMD) in various world regions increases the risk of WMD being employed against the United States and its allies during contingency operations. Potential for terrorist use of NBC materials against U.S. or allied operations is a very real threat. The Tokyo, Japan, subway incident underscores the potential of terrorist activity involving NBC materials. Despite existing treaties and ongoing treaty negotiations, NBC weapons proliferation is a continuing threat.

The objectives of the NBC Mission Area are to provide U.S. forces with the capability to detect and survive an initial NBC attack and to effectively sustain mission operations with minimal casualties and equipment degradation; to provide electro-optical obscuration material to screen U.S. assets from enemy Precision Guided Weapons and Reconnaissance, Surveillance, and Target Acquisition (RSTA); and to provide smoke/obscurants and target defeating capabilities which allow achievement of military objectives with minimal collateral damage. The technology investment in support of these objectives is covered below.

2. Relationship to Operational Capabilities

NBC modernization efforts reflect the needs of the Joint Services. Through a series of wargames sponsored by the TRADOC Battle Labs, the "Voice of the Warfighters" is being captured for both wartime and other military missions. Table III-K-1 represents the link between NBC Systems/System Upgrades/Advanced Concepts (S/SU/ACs) and Battlefield Dynamics.

Table III-K-1. NBC Systems Capabilities

S/SU/AC FUNCTION	BATTLEFIELD DYNAMICS: Early Entry	Depth and Simultaneous Attack	Mounted Battlespace	Dismounted Battlespace	Battle Command	Combat Service Support	SYSTEM/SYSTEM UPGRADE CAPABILITIES	ADVANCED CONCEPT CAPABILITIES
DETECTION								
Systems/System Upgrades							*Chemical:*	*Chemical:*
Chemical Detectors	●	○	●	●	●	●	• Chemical Early Warning contamination monitoring system that quantifies, ranges, and maps • Miniature chemical detector • Chemical water monitor	• Long range chemical imaging detector for aircraft, UAVs, and high altitude aircraft
Biological Detectors	●		●	●	●	●		*Biological:* • Generic biodetection and identification at asymptomatic levels
Advanced Concepts							*Biological:*	
Chemical Detectors	●	○	●	●	●	○	• Bio Early Warning up to 50 km	• Rapid automated biodetection
Biological Detectors	●		●	●	●	●	• Bio point detection + ID system	• ID of bioagents at increased sensitivities (1 ACPLA)
PROTECTION AND SURVIVABILITY								
Systems/System Upgrades								
Individual Protection	●		○	●		○	• Integrated respiratory protection: communication, vision, and compatibility with weapon sights • Reduced physiological burden and mission degradation • Increased confidence in CB protective equipment	
Collective Protection	●	○	●	●	●	●	• Improved entry/exit of collective protected combat vehicles • Advanced integrated filtration with environmental support systems • Regenerable filtration system tailored to host system • Reduced logistic support	• Residual life indicator for filters • Regenerable filtration (vapor and particulate)
Advanced Concepts								
Individual Protection	●		○	●		○	• Continuous filtration tailored to light vehicles	
SUSTAINMENT								
Systems/System Upgrades								
Decontamination	●		●	●		●	• Decon downtime reduced • Less labor intensive	• All agent decon • Decon without water • Less labor intensive decon • Rapid, self-decon coatings
Advanced Concepts								
Decontamination	●		○	○		●		• Imaging detector to highlight contaminated areas and decon efficacy • Corrosivity eliminated • Environmentally safe
COUNTER RSTA/DECEPTION								
System/System Upgrades								
Smoke/Obscurants	○	○	●	●		●	• Screening, camouflage, and decoy capabilities in visible, IR, and MMW ranges • Logistically acceptable • Env ironmentally safe	
Advanced Concepts								
Smoke/Obscurants	●	○	●	●				• Smart weapons defeat capability • EO marker for Combat ID • DEW defeating obscuration
MANEUVER/FIRE SUPPORT								
Advanced Concept								
Target Defeat Capabilities	○	●	●	●				• Defeat/immobilize enemy threat equipment, i.e., trucks, tanks • Close-in fire support for SOF, MOUT • Increased first kill capability of hardened targets • Large area defeat of enemy threat equipment

● Provides Significant Capability ○ Provides Some Capability

3. Modernization Strategy

The NBC Modernization strategy reflected in this chapter represents the emerging joint NBC defense strategy in Detection, Protection, Decontamination, and the Army strategy in Smoke/Obscurants. The joint NBC modernization strategy is focused on biological agent point detection, and remote early warning detection (chemical and biological). Efforts in Decontamination and Individual Protection, recently at a low level, are being increased in recognition of their payoff to sustainment of the forces and increased mobility. Collective protection efforts remain significantly reduced and refocused to provide far term capabilities. A capability to identify significant improvements in decontamination is being maintained. Also included in the NBC section is a subsection on Smoke/Obscurants and Target Defeating technologies.

NBC Defense

Protecting the Force is paramount in the joint NBC defense strategy. Early detection and warning is key to this strategy by providing situational awareness and the capability of U.S. forces to counter any NBC threat. Chemical and Biological detection systems, fully integrated in the digital battlefield, will enable battlefield commanders to detect NBC warfare agents at operationally significant levels and immediately activate protective or avoidance measures. Decision aids will assist commanders at all levels. The goal of protection is to insulate forces from NBC agents using clothing ensembles and respirators as well as collective filtration systems for weapons systems and shelters. By carefully balancing performance requirements with human physiological and psychological parameters, individual protection technologies will enable the forces to sustain their mission with minimal casualties or degradation of capabilities when an NBC threat is encountered. Integrated Environmental Control and longer life NBC protection will be provided for an increasing need in collective protection for command posts, soldier comfort, and medical needs. When NBC contamination cannot be avoided, decontamination systems and point detectors will be used to expedite reconstitution of contaminated personnel and equipment. New decon technologies and systems will minimize logistics burden and reduce contamination impact on mission effectiveness. CB modeling and simulation technologies are being enhanced to assess doctrine, training, and materiel operating in an NBC environment, to provide equipment design parameters, and to serve as a real-time decision aid for battlefield commanders. The following goals define the NBC Defense Strategy:

- Provide rapid field biodetection capability.
- Extend range and coverage of chemical and biological Standoff Detection capabilities.
- Integrate chemical and biological sensors with the digitized battlefield.
- Maintain current protection capability while reducing degradation associated with individual protective equipment.
- Develop continuous, regenerable collective protection filtration systems integrated with environmental controls requiring minimal logistics.
- Develop effective, low environmental impact decontamination systems which do not damage contaminated surface.
- Enhance CB modeling and simulation capabilities to allow concept evaluations, hazard assessment, and realistic training for the CB contaminated battlefield.

Smoke/Obscurants

Smoke and obscurants provide a potent combat multiplier for increasing the effectiveness of certain weapons systems, countering enemy RSTA efforts, and supporting deception operations. The thrust of the smoke/obscurant technology strategy is:

- Enhance the capability of smoke/obscurants to defeat enemy RSTA capabilities which allow the maneuver forces to dominate management and control of the electromagnetic (EM) spectrum.

Target Defeat Capabilities (TDC)

Target Defeat Capabilities will provide an increase in weapons effectiveness across the spectrum of conflict and throughout the range of weapons systems from soldier-fired to smart munitions. The TDC modernization strategy is to pursue limited, high payoff capabilities with strong user support:

- Increase the effectiveness of flame/incendiary munitions to attack both large area and hardened targets.
- Support MOUT/Peacekeeping and other missions requiring operations among noncombatants.
- Field expedient foams for enhanced soldier survivability.
- Enhance delivery of riot control agents for crowd control.

Modernization efforts will be implemented through horizontal integration of NBC capabilities into major weapon systems. NBC materiel acquisition will be conducted via technology insertions, product improvements, and advanced concepts. Integration efforts such as these will ensure significant gains in operational survivability and mission sustainment at modest incremental costs. The Joint NBC modernization strategy is postured to meet the challenges facing U.S. forces in the 21st Century.

4. Roadmap for NBC Systems

Figures III-K-1a, 1b, and 1c are the roadmaps for CB Defense, Smoke/Obscurants, and TDC. Table III-K-2 summarizes the demonstrations and systems found in these figures. This strategy emphasizes technology demonstrations incorporated into the front end of critical development programs. These demonstrations will significantly reduce development risk, verify the system integration of advanced technologies, and facilitate technology insertions, where possible.

a. CB Defense

The Chemical/Biological Defense program emphasizes detection, protection, (individual and collective) decontamination, and modeling and simulation. The roadmap for CB Defense is shown in Figure III-K-1a.

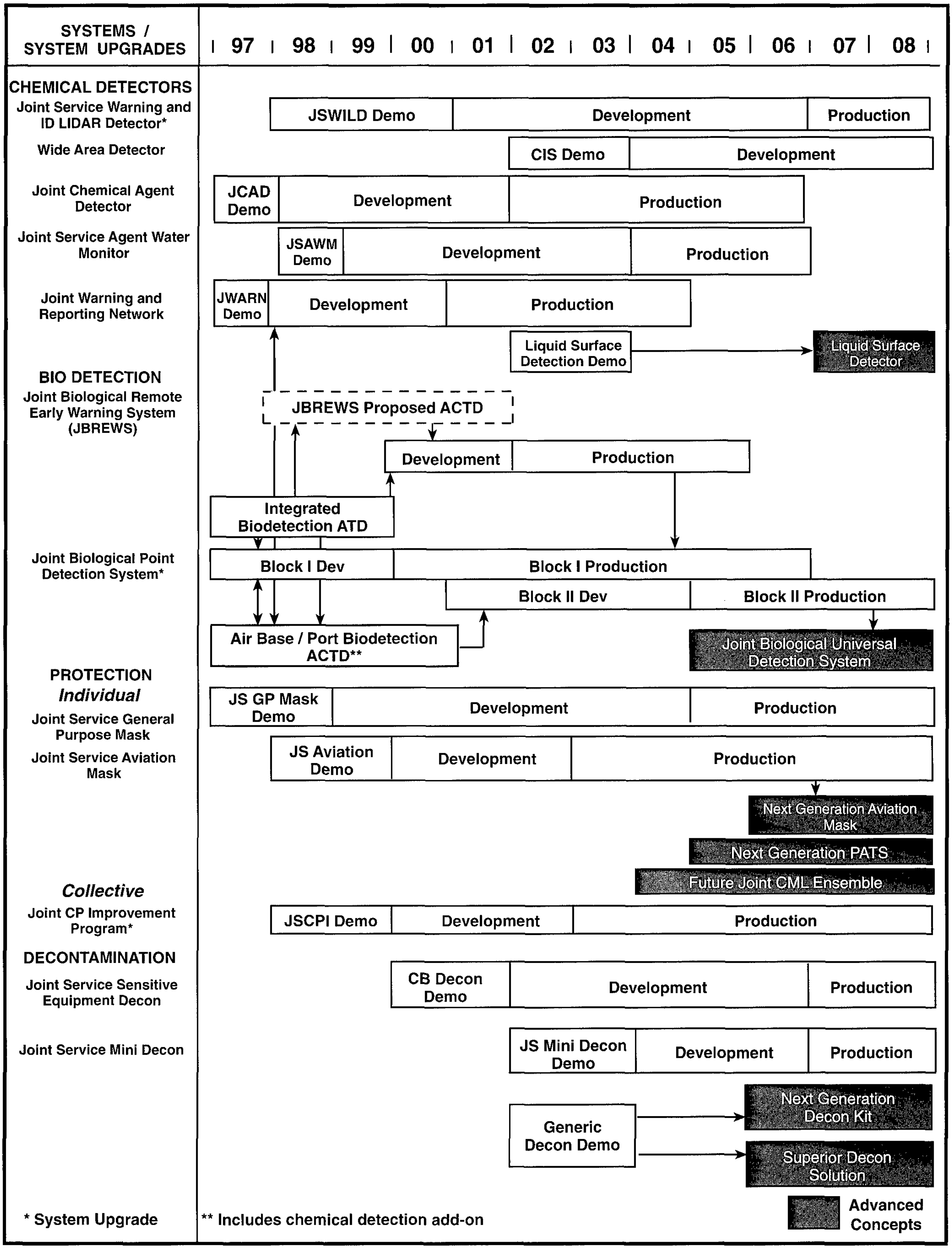
The detection portion of CB defense is divided into two categories: chemical detectors and biological detectors. Both remote early warning and point detection technologies are being pursued for chemical and biological detectors.

Table III-K-2. NBC Systems Demonstration and System Summary

ATDs	TECHNOLOGY DEMONSTRATIONS
• Integrated Biodetection* **ACTD** • Air Base/Port Biological Detection (includes chemical detection add-on) • Biological Remote Early Warning (proposed) *This ATD is OSD funded. (See Volume II, Annex B, for additional information.)	**CB Defense** • Joint Service Warning and Identification LIDAR Detector (JSWILD) • Chemical Imaging Sensor • Joint Chemical Agent Detector (JCAD) • Joint Service Agent Water Monitor (JSAWM) • Joint Warning and Reporting Network (JWARN) • Liquid Surface Detection • Joint Service General Purpose Mask (JSGPM) • Joint Service Aviation Mask (JSAM) • Percutaneous Protection • Joint Collective Protection Improvement • Chemical and Biological Decontamination • Joint Service Mini Decontamination System • Generic Decon **Smoke/Obscurants** • Millimeter Wave Screening • Electro Optical System • Multispectral Smoke **Target Defeat Capabilities** • Target Defeat Capability

SYSTEMS/SYSTEM UPGRADES/ADVANCED CONCEPTS	
Systems/System Upgrades (*)	***Advanced Concepts***
• Joint Service Warning and Identification LIDAR Detector (JSWILD) • Joint Biological Point Detection System • Joint Collective Protection Improvement • Large Area Smoke System, M56 P3I (MMW Module)	• Liquid Surface Detection • Joint Biological Universal Detection System • Next Generation Aviation Mask • Next Generation PATS • Future Joint Chemical Ensemble • Next Generation Decon Kit • Superior Decon Solution

Figure III-K-1a. Roadmap for CB Defense



The goal of CB detection is to provide a real-time capability to detect, identify, locate, map, and quantify the presence of all CB warfare agent threats at levels below hazardous levels and to disseminate this information rapidly. Current emphasis is on multi-agent sensors for point biological agent detection and remote early warning chemical and biological detection. In the near term, a number of individual sensors are being developed while detection technology matures. In particular, a miniaturized chemical vapor point detector and an automated biological point detector will be available. Far-term objective technologies focus on the integration of chemical and biological detection into a single sensor suite. Technology emphasis is on detection sensitivity and specificity across the entire spectrum of CB agents, programmable for emerging threats, system size and weight, detection range, and signature and false alarm rates. Integration of CB detectors into various platforms (vehicles and aircraft) and C3I networks constitutes the ultimate focus of this technology area.

The CB protection area covers technology efforts to provide CB protection for the individual warfighter as well as enclosures where groups of personnel require collective protection from the contaminated environment. The goal of respiratory protection technology efforts is to develop the next generation respiratory protection equipment for the 21st Century warfighter. This equipment will afford protection against current and future threats, minimize mission degradation, and improve system integration and compatibility; collective protection technology is focused on developing air purification systems for buildings, shelters, vehicles, aircraft, and ships that must operate in CB warfare agent contaminated battlefield conditions. Current efforts are directed at regenerative filtration technologies, deep-bed impregnated carbon, and single pass filters with novel impregnated materials to reduce overall cost, size, weight, and power to facilitate widespread application.

The goal for decontamination technologies is to develop effective, environmentally low impact CB decontamination systems to neutralize or break down toxic materials without damaging the contaminated surface or affecting the performance of the equipment being decontaminated. This area includes decontamination of personnel, personal individual equipment, tactical combat vehicles and equipment, sensitive electronics, cargo areas of aircraft, seagoing vessels, and critical assets in fixed sites. Due to increased user interest, funding in this area has been enhanced. Studies will focus on the use of supercritical carbon dioxide, sorbents, solution decontamination, and enzyme-based systems.

Modeling and simulation technologies are being investigated to provide enhanced command evaluations, to integrate sensor data and to permit realistic training and simulation of the CB battlefield environment. The information generated will provide decision aids to commanders to allow tradeoffs among tactical options as well as assessment of Joint Services doctrine, training, leadership, organization, materiel, and warfighter performance during and after a CB attack. Modeling and simulation technologies will be used to evaluate the battlefield value-added potential of developmental and conceptual NBC systems and will become an integral part of every development program and every phase of the acquisition cycle. A current thrust is to incorporate terrain, mesoscale meteorology, and objects such as tanks, ships, or buildings into CB effects hazard assessment models and to incorporate these models into new and existing combat simulations such as MODSAF and Distributed Interactive Simulations (DIS).

Joint Service Warning and Identification LIDAR Detector (JSWILD) (98-00). This demonstration will emphasize joint service operation with shipboard testing and airbase defense demonstrations. Previous work has demonstrated the feasibility of using IR LIDAR to detect vapors of nerve agents and also shown great promise in the detection of large droplets of nerve agents. In addition, the detection of aerosol particles of all sizes and compositions will be demonstrated and sensitivities determined for each application. All service interferences will be identified and introduced into the existing model for inclusion into the pattern recognition detection algorithm during subsequent development. The goal of this demonstration is to determine capabilities and limitations for each possible mission (ship defense and fixed site defense). **Supports:** Airbase Defense and Shipboard Warning, JSWILD, JSNBCRS.

Biological Remote Early Warning Advanced Concept Technology Demonstration (Proposed) (97-01). The objective of this ACTD is to evaluate the military utility of remote early warning for biological warfare attacks against U.S. forces and to develop operational procedures associated with that capability. The ACTD will demonstrate several remote early warning platforms. All the remote detectors will be connected to a warning and reporting system that promptly alerts forces who are downwind of biological warfare agents. The ACTD will leverage advanced biological detection technologies from the DoD counterproliferation initiative and technology base community. Extensive simulation will be conducted in parallel to evaluate the operation utility of the remote early warning system during all phases of warfighting operations. **Supports:** Joint Biological Remote Early Warning System (JBREWS).

Integrated Biodetection ATD (96-99). The Integrated Biodetection ATD will demonstrate point detection and remote early warning of biological agents using two state-of-the-art technologies. In addition, multi-year 6.2-technology base efforts are being carried out in both areas to support and ensure the successful demonstration of the ATD technologies in FY96-99. The ATD will focus on point biosensors that incorporate Automated DNA Diagnostic technology to identify biological agents with the highest known degree of specificity and sensitivity in addition to increasing current reliabilities, stabilities, and response times of fielded and near-term P3I biosensors. These state-of-the-art biological identification devices are planned for incorporation into the Joint Biological Point Detection System (JBPDS) as next generation biosensors. A rapid, real-time Biological Aerosol Warning System using small, micro-UV laser-based, fluorescent particle counters will also be demonstrated. Its purpose is to provide an early warning/alert of a threat biological aerosol cloud to high value battlefield assets. The key to the demonstration is to show the technologies in a unified effort in a battlefield exercise providing detection and warning of biological agents before forces are adversely affected, thus reducing casualties. **Supports:** JBPDS, Biological Standoff Detection Systems, Air Base/Port Biodetection ACTD, Proposed Biological Remote Early Warning ACTD.

Air Base/Port Biological Detection ACTD (96-00). The Air Base/Port ACTD objective is to evaluate the military utility of an air base or port biological detection perimeter capability and to develop operational procedures associated with that capability. An additional objective is to provide a residual capability adequate to detect, alarm/warn/dewarn, identify, protect, and decontaminate against a biological warfare (BW) attack on an air base or port facility. The air base or port residual capability will consist of a perimeter biological detection capability, laboratory agent identification capability, dewarning procedures, C4I connectivity with theater NBC reporting system, medical countermeasures, oronasal protection, collective protection, and decontamination procedures and capability. This ACTD will also include a chemical add-on capability which will utilize mature and available technology (passive IR spectrometry and ion trap spectroscopy) to automatically detect and identify chemical threat agents in near real time (less than 30 seconds). Additionally, this chemical add-on will provide the CINCs a first time capability to network legacy and emerging biological and chemical detectors and will produce automated warnings and reportings for enhanced battlefield visualization and force protection as defined in Joint Vision 2010. **Supports:** JBPDS.

Chemical Imaging Sensor Demonstration (02-03). This sensor will expand the capability of current passive interferometry and signal processing to allow long-range chemical imaging. The sensor will be capable of detecting known chemical agents and can be programmed to detect other militarily significant spectral data. It will also provide a visual display of the hazard area. Extended detection range capability will be provided for use on aircraft and high altitude reconnaissance systems. Program will use design and performance data developed in Project Safeguard. **Supports:** Wide Area Detection.

Joint Chemical Agent Detector (JCAD) (97). The JCAD (formerly titled the Joint Service Chemical Miniature Agent Detector) has been accelerated to transition one year earlier than planned. It will demonstrate an advanced lightweight chemical detection concept capable of selective detection of low asymptomatic/subsymptomatic levels of chemical agents. The demonstration will focus on small size, low electrical power consumption, and reliable detection of known chemical agents. The JCAD will be capable of integration with Force XXI Land Warrior (FXXI LW) sensors and communication equipment. The program includes evaluation of ion mobility spectrometry, surface acoustic waveguide, and other technologies. **Supports:** FXXI LW, Chemical Detectors (Small Lightweight Chemical Detector).

Joint Service Agent Water Monitor (JSAWM) (98). The Joint Service Agent Water Monitor will demonstrate both an in-line (USAF) and a portable batch water test capability. JSAWM will be capable of detecting chemical agents below the revised U.S. Army Surgeon General's requirements for chemical agents and also be able to detect a range of waterborne biological agent contamination down to parts per million. The system will rapidly evaluate water and provide near real-time alert if water becomes contaminated so that immediate action can be taken to prevent ingestion by warfighters. **Supports:** In-Line Water Monitor (USAF) and Agent Water Monitor (U.S. Army Quartermaster).

Joint Warning and Reporting Network (JWARN) (97). JWARN (formerly titled NBC Oracle JWARS) will demonstrate the integration of off-the-shelf versions of JWARN Sensor Link (SL), JWARN Hazard Prediction Tool (HPT), and the JWARN Automated NBC Warning and Reporting System (ANBCWRS). JWARN will provide commanders, military forces, and civilian officials with near-real-time situational awareness of NBC and WMD hazards by integrating NBC sensors with Service C4I systems to provide fully automated and intelligent NBC and WMD prediction, warning, and reporting. **Supports:** JBREWS, JBPDS, JCAD, Battlefield Digitization.

Liquid Surface Detection (02-03). This effort will culminate in the development of both active and passive detection systems for detection and identification of chemical agent liquid surface contamination for the purpose of reconnaissance and contamination avoidance and decontamination effectiveness. **Supports:** reconnaissance (air and ground), stand-off detection (vehicle and fixed site), alarms/monitors, and warning and reporting.

Joint Service General Purpose Mask (97-98). A variety of advanced respiratory protection concepts are being investigated for application to a Joint Service eye/respiratory protection system for ground use and possibly for use in Army aviation applications. The general purpose mask will provide protection against current and future chemical/biological threats, reduced physiological and psychological burden and resulting mission degradation associated with individual protection equipment, and improved integration with future soldier (i.e., weapons sighting systems, night vision equipment, helmets and helmet-mounted displays). Technology efforts will focus on improved filter design and filtration media, lens design and materials, and agent resistant faceblank materials. Advancements in protection and performance testing to support assessment to anticipated standards are included in these efforts. **Supports:** Joint Service General Purpose Mask, FXXI LW, and Air Warrior.

Joint Service Aviation Mask (JSAM) (98-99). The Joint Services are supporting this technology effort to develop a protective mask system for high-performance aviation requirements and possibly for use by rotary-wing pilots (including Army aviation). The effort will focus on consolidation of requirements from a series of high-performance aviation mask systems, some of which are not intended to provide protection against chemical or biological agents. The "Combat Ace" mask system is a likely candidate for the baseline JSAM system. Various mask technologies and designs will transition to the JSAM program as they become available. **Supports:** Joint Service Aviation Mask, FXXI LW.

Joint Service Collective Protection Improvement (formerly titled Advanced Filtration Concepts) (98-99). Several advanced CB filtration concepts will be evaluated to prove feasibility in implementing improved filtration technologies into various combat system applications. Technologies investigated will include regenerable filtration systems, catalytic systems, improved sorbents, and improved biological filtration media. Advanced filtration concepts demonstrate reduced size and weight potential, improved filtration capability, elimination of filter change out (except at scheduled maintenance periods), and integration with power and environmental control systems. **Supports:** AFAS/FARV and Comanche, NBC Collective Protection System [Advanced Deployable Collective Protection (CP) for Fixed Sites, Advanced Lightweight Collective Protection System].

Chemical/Biological Decon (00-01). This demonstration will consist of using a closed loop recirculating supercritical carbon dioxide system to remove chemical and biological materials from sensitive equipment items and the use of surbent and solution technologies for decontamination of sensitive interiors. Enzyme components will be evaluated for potential use in surface decontamination of sensitive equipment and other applications. These new decontaminants will reduce manpower constraints and logistics burden over present assets. **Supports:** Joint Service Sensitive Equipment Decon System.

Joint Service Mini Decon (02-03). This program will demonstrate a concept for a manportable modular decon system to support the warfighter's needs, in particular the dismounted forces and the Marine Corps. Enzyme components will be evaluated for potential use in surface decontamination of sensitive equipment and other applications. **Supports:** Joint Service Mini-Decon System.

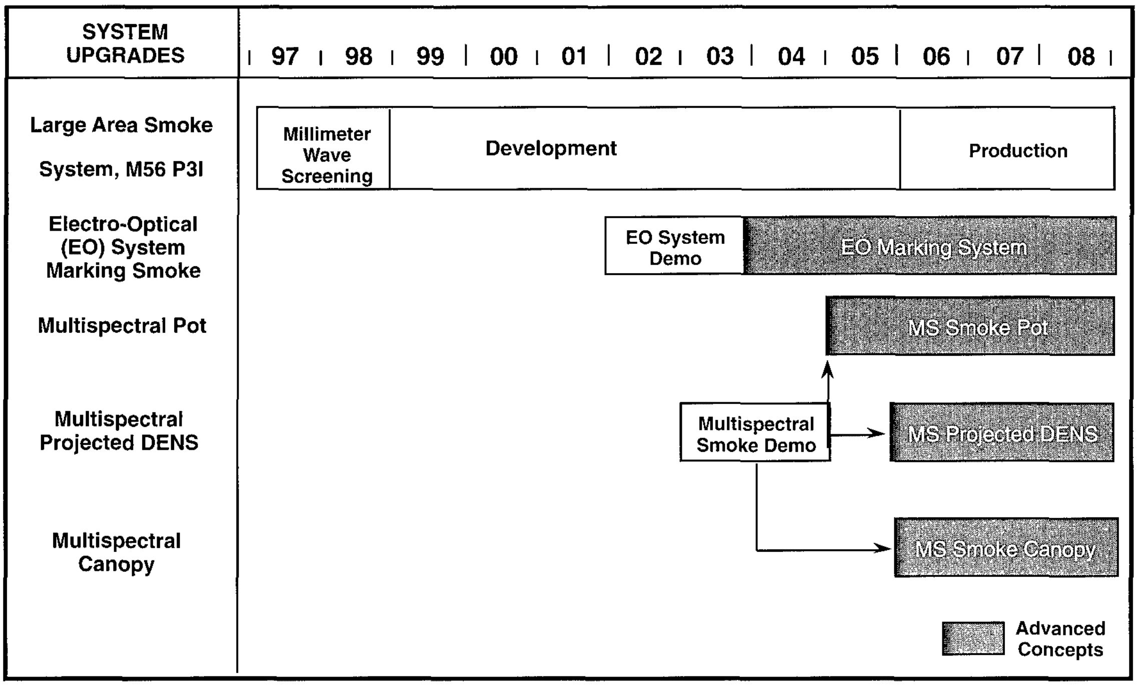
Generic Decon (02-03). The use of non-toxic, material compatible, and environmentally safe decon will be evaluated. Technologies investigated will include high capacity surfactants, sorbent systems, reactive organic solutions. Enzyme components will be evaluated for potential use in surface decontamination of sensitive equipment and other applications. **Supports:** Joint Service Mini Decon System.

b. Smoke/Obscurants

In response to the proliferation of increasingly sophisticated RSTA capabilities throughout the Electro-Magnetic (EM) spectrum, the Smoke/Obscurant strategy capitalizes on technologies capable of providing multispectral screening. These environmentally and logistically acceptable, multispectral materials will counter enemy RSTA activities in broader ranges of the EM spectrum for self-defense, large area coverage, and projected applications. The roadmap for Smoke/Obscurants is shown in Figure III-K-1b.

Millimeter Wave Screening (97-98). This demonstration will determine the feasibility of a millimeter wave (MMW) obscurant generating system in preventing threat radars from observing, acquiring, targeting, and tracking friendly targets. The module will expand the capability of the current M56 Large Area Smoke Generator, which screens only the visual and infrared (IR) bands. Aerosol technology, chemical dispersion techniques, and dissemination mechanisms will be exploited. **Supports:** Smoke/ Obscurants (M56 P3I).

Figure III-K-1b. Roadmap for Smoke Obscurants



Electro Optical (EO) System Marking Smoke (02-03). This demonstration will consist of a personal smoke grenade that will release a material detectable only by a mid- or far-IR sighting device. The grenade is intended for ground force use as a signaling device to mark landing and drop zones. It also has application for pilot rescue missions and combat identification. This demonstration will explore cryogenics, exothermic reactive materials, and reaction control techniques. **Supports:** Smoke/Obscurants (Electro-Optical System Marking Smoke).

Multispectral Smoke (03-04). This demonstration will exhibit the following capabilities:

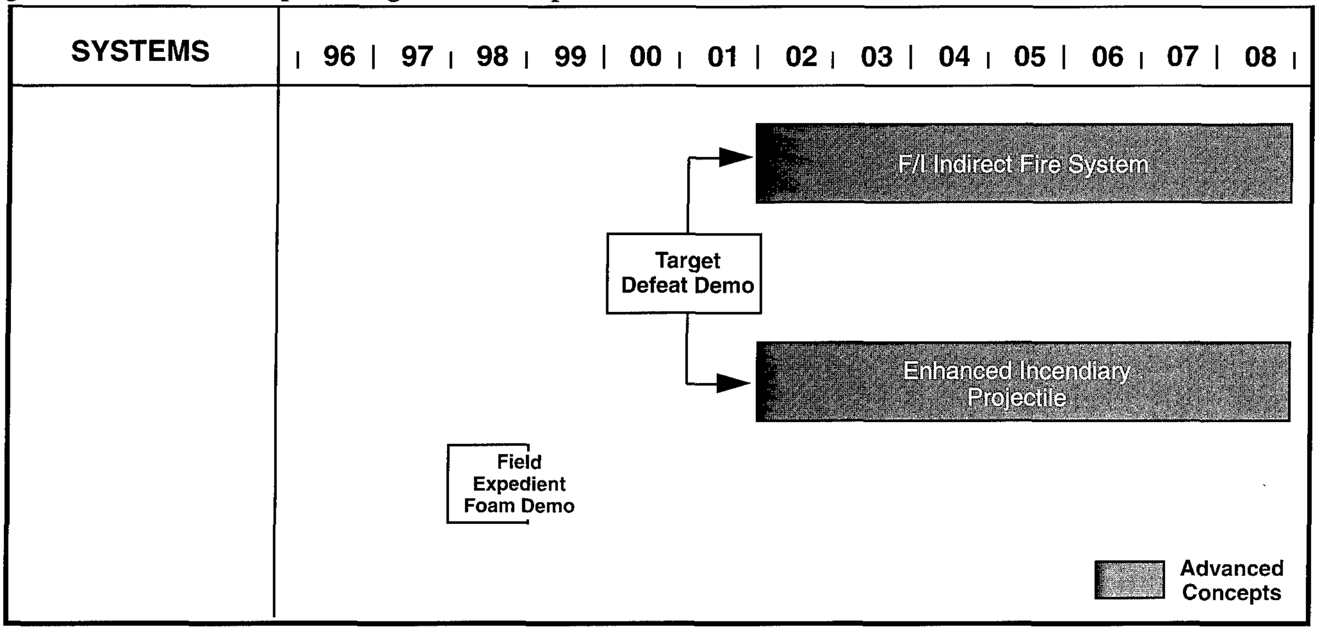
- A smoke pot capable of providing visual through MMW obscuration that will supplement and/or provide screens independent of other large area smoke systems. Smoke pots will be kept as light as possible while providing screening times equal to or greater than those of existing smoke pots. Screening material will be toxicologically and environmentally safe for use in both combat situations and training exercises. **Supports:** Smoke/Obscurants (MS Smoke Pot).
- A Direct Energy Weapons (DEW) defeat capability for the remote, rapid neutralization of threat directed enemy weapons on a point or limited area basis. This project munition will be toxicologically or environmentally safe for use in both combat situations and training exercises. **Supports:** Smoke/Obscurants (MS Projected DENS).
- Smart Weapons Defeat capability using a smoke grenade system to break the target acquisition lock of a smart weapon in IR sensor and divert the munition from its intended target. Exortermic reactive materials and high speed dissemination techniques will be highlighted. As a follow-on to this effort, an Autonomous Smart Weapons Defeat capability will be demonstrated. The system will defeat the threat and automatically activate the countermeasure for survivability. Emphasis will be in using laser detection in conjunction with obscurant technologies. **Supports:** Smoke/Obscurants (MS Smoke Canopy).

c. Target Defeat Capabilities (TDC)

Future efforts in the TDC area will be directed toward various classes of target sets through the use of lethal combined-effects payloads and innovative antimateriel means. These munitions will defeat or degrade enemy armored targets and disrupt operational tempo by exploiting vulnerable areas of armored vehicles, logistic supply lines, and other militarily significant targets. The roadmap for TDC is shown in Figure III-K-1c.

Target Defeat Capability (00-01). This demonstration will focus on a unique payload concept that will increase the operational effectiveness of conventional weapons. Flame/

Figure III-K-1c. Roadmap for Target Defeat Capabilities (TDC)



incendiary technology will be used to defeat, degrade, or immobilize enemy targets. This unique approach will provide both direct and indirect fire support capabilities across the battlefield. This concept will also demonstrate the increase in terminal effectiveness from combined effects greater than conventional warheads of the same caliber and explosive weight. Energetic materials, high energy oxidizers, and other pyrotechnics will be investigated for use in conjunction with existing military weapon systems. **Supports:** TDC [Flame Incendiary (F/I) Indirect Fire System and Enhanced Incendiary Projectile].

Field Expedient Foam (98). Target Defeat Capability also includes investigation of both aqueous and rigid foam technologies. The rigid foams program represents a technology investigation and evaluation program, coupled with state-of-the-art and emerging foam materials and technologies, which could provide the ability to construct field barriers and foxhole covers; create fragmentation barriers with Kevlar cloth; and seal doors, windows, and other entrance ways. Antimateriel applications and use as a mine countermeasure through "freezing up" of the mine's firing mechanism are also under investigation. The aqueous foams program investigates aqueous foam formulations and the ability to disseminate large volumes of aqueous foams both for area denial and intruder confusion. The addition of irritants to aqueous foams for crowd denial and dispersion is also being investigated. **Supports:** TDC.

5. Relationship to Modernization Plan Annexes

Figure III-K-2 illustrates the linkage between the NBC S/SU/ACs and the other Modernization Plan Annexes which they support.

Figure III-K-2. Correlation Between Nuclear/Biological/Chemical S/SU/ACs and Other Army Modernization Plan Annexes

NUCLEAR/BIOLOGICAL/CHEMICAL SYSTEMS/SYSTEM UPGRADES/ADVANCED CONCEPTS		Soldier Systems	Close Combat Light	Aviation	Mounted Forces	Engineer & Mine Warfare	IEW	Air Defense Artillery	Fire Support	C4	Theater Missile Defense	Combat Health Suppor	Space
Systems/ System Upgrades	NBC Individual Protection	●	○	●	●							○	
	NBC Collective Protection		○	●	●	○		○		●	○	●	
	Chemical Detectors	●	●	○	●	○	○	○		○	●	●	
	Biological Detectors	●	●	○	●		○	○		○	●	●	
	Smoke/Obscurants	○	○		○	○	○	○			●		
Advanced Concepts	NBC Individual Protection		○	●		○		○		●	○	●	
	Chemical Detectors	●	●	○	●	○				○	●	●	○
	Biological Detectors	●	●	○	●	○				○	●	●	
	NBC Decontamination	●	●	○	○							●	
	Smoke/Obscurants	●	○		●	○	○	○			●		
	Target Defeat Capabilities	○	●					●	●		●		

● System plays a significant role in the Modernization Strategy.

○ System makes a contribution to the Modernization Strategy.

L.

Air Defense Artillery

Not the cry, but the flight of the wild duck,
leads the flock to fly and follow.
Chinese Proverb

1. Introduction

As the 21st Century approaches, Air Defense Artillery (ADA) must be ready to meet the challenge of the evolving air and missile threat while continuing to support force projection operations in major regional contingencies, protect the United States in coordination/cooperation with joint air defense systems and execute military operations other than war missions. The air and missile threat is often the single greatest risk to the successful conduct of force projection operations, particularly during early entry and decisive operations. With many nations acquiring technologically advanced, highly lethal weapons such as ballistic missiles, our ADA force can expect to face a much more diversified threat in the future. Threat capabilities of other nations beyond the year 2000 will require that the ADA force be capable of dominating battlespace to achieve decisive victory by winning quickly with minimal casualties.

The mission of ADA is to protect the force and selected geopolitical assets from aerial attack, missile attack, and surveillance. To meet its mission requirements and counterthreat capabilities, the ADA Force XXI must be a strategically deployable, highly mobile, and versatile force, trained and equipped to go to war anywhere in the world on short notice and must be highly lethal and capable of battlefield survival. The air defense mission includes National Missile Defense (NMD) of the continental United States and anti-satellite defense, as well as Theater Missile Defense (TMD), which protects the force from theater missile attacks. Both NMD and TMD are addressed in Volume II, Annex D.

Successful execution of future operations will require increased emphasis on planning and conducting joint and multinational operations. The capabilities of many weapons and forces must be integrated to achieve the operational commander's air defense objectives.

2. Relationship to Operational Capabilities

To achieve the required operational capabilities, a balanced materiel development and demonstration strategy must be followed. Multifaceted technology base efforts have been initiated across the full spectrum of tactical through strategic requirements. Initiatives emphasize survivable target acquisition (both passive and active) and positive identification; cost-effective fusion of multiple sensor/processor modules into automated target acquisition and fire control suites; multiple missile guidance modes against the reactive threat; high energy, insensitive propellants, and alternate propulsion concepts; missile seeker upgrades to integrate advanced fuzing techniques and smart focal plane arrays; hit-to-kill technology; mobile, lightweight, and increased firepower; dispersed, distributed, survivable command and control (C2) and supporting communications; and an integrated training architecture that fully exploits the materiel capability. Table III-L-1 shows the correlation between Air Defense systems/system upgrades/advanced concepts (S/SU/ACs) and the six TRADOC Battlefield Dynamics and displays in general terms the operational capabilities for Air Defense S/SU/ACs.

3. Modernization Strategy

The Air Defense Artillery and Theater Missile Defense Modernization Plan annexes detail a disciplined approach to providing air and missile defense support to both theater and maneuver forces. The Air Defense Modernization Strategy focuses on the following objectives:

- Achieve near leakproof theater missile defense this decade
- Address the full threat spectrum
- Respond to warfighting doctrine
- Maintain a technological advantage

4. Roadmap for Air Defense Artillery

Table III-L-2 presents a summary of demonstrations and systems found in the Air Defense Artillery roadmap (Figure III-L-1). Modernization

Table III-L-1. Air Defense Artillery System Capabilities

S/SU/AC FUNCTION	BATTLEFIELD DYNAMICS: Early Entry	Depth and Simultaneous Attack	Mounted Battlespace	Dismounted Battlespace	Battle Command	Combat Service Support	SYSTEM/SYSTEM UPGRADE CAPABILITIES	ADVANCED CONCEPT CAPABILITIES
KILL SYSTEMS								
System								
Corps SAM	●	●	○	○	●	○	• Missile defense • Highly mobile • Rapidly deployable by C-130 • Modular • High firepower • Multimode seeker • Lethality enhancements	
System Upgrade								
Patriot PAC-3	●	●	●	●	●	○	• Missile defense • High firepower • Expanded engagement envelope • Hit to kill • Increased mobility/survivability • 3-D surveillance and tracking • Low radar cross section targets • Highly mobile • Targets in clutter	
Bradley Stinger Fighting Vehicle —Enhanced (Linebacker)	●		●	○				
Advanced Concepts								
Stinger Block II	●	○	○	●	●	○		• IR counter-countermeasures • Improved lethality against helicopter • 360 degree coverage

● Provides Significant Capability ○ Provides Some Capability

Table III-L-2. Air Defense Artillery Demonstration and System Summary

ATDs	TECHNOLOGY DEMONSTRATIONS
• Multi-Function Staring Sensor Suite (see Mounted Forces) (See Volume II, Annex B, for additional information)	• Masked Targeting (MT) • 2.75-Inch Anti-Air • Ducted Rocket Engine (DRE) • Future Missile Technology Integration (FMTI) • Compact Kinetic Energy Missile (CKEM) • High Mobility Ground Launched AIM-120 Advanced Medium Range Air-to-Air Missile (HMGL-AMRAAM) • Electronic Integrated Sensor Suite for Air Defense (EISS-AD) • Guidance Integrated Fuzing • Armicide

SYSTEMS/SYSTEM UPGRADES/ADVANCED CONCEPTS

Systems

- Corps SAM

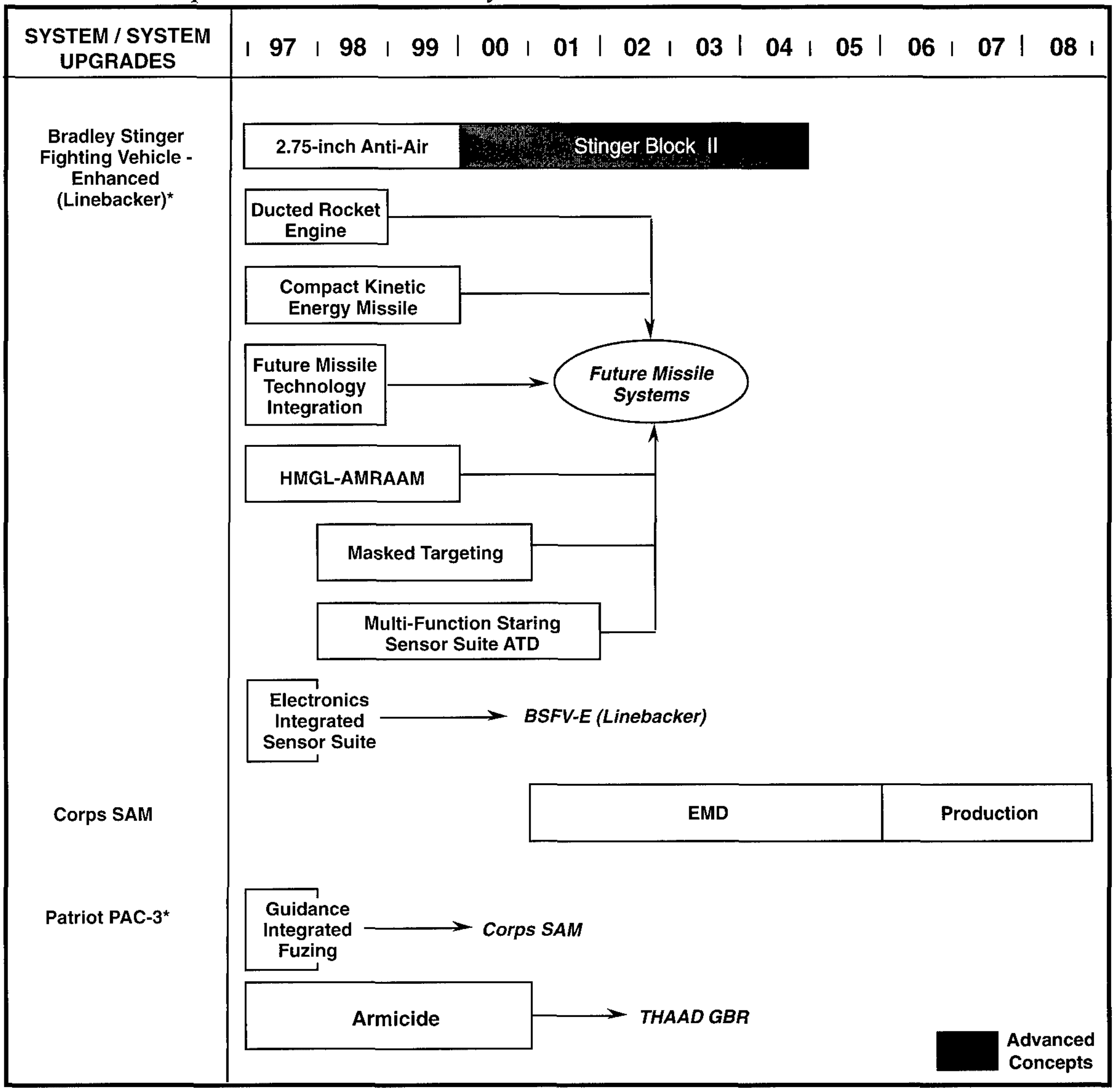
System Upgrade

- Patriot PAC-3
- Bradley Stinger Fighting Vehicle–Enhanced (Linebacker)

Advanced Concepts

- Stinger Block II

Figure III-L-1. Roadmap for Air Defense Artillery Modernization



* System Upgrade

of ADA depends upon the development of these key systems for air defense coordination.

a. Advanced Technology Demonstrations Leading to Modernization of Air Defense Artillery Units

Air Defense Artillery systems consist of a complementary mix of weapons, sensors, and command and control systems. Air Defense Artillery modernization focuses on S/SU/AC developments and their associated demonstrations. The Multifunction Staring Sensor Suite (MFS3) ATD will have a major impact on the Air Defense mission. Additionally, the mission area will derive benefits from many other ATDs, to include: the Rapid Force Projection Initiative ACTD, the Target Acquisition and Battlefield Combat Identification ATDs, and the recently completed Combined Arms Command and Control and Bistatic Radar for Weapons Location ATDs.

Multifunction Staring Sensor Suite (MFS3) ATD (98-01). The MFS3 ATD will integrate multiple advanced sensor components including staring infrared arrays, multifunction laser, and acoustic arrays. In support of air defense, it will demonstrate the capability for automated surface-to-surface, surface-to-air, and air-to-ground search, acquisition, and non-cooperative identification. More detailed information can be found in Section G, *Mounted Forces*. **Supports:** BSFV-E (Linebacker).

b. Technology Demonstrations Leading to Modernization of Air Defense Artillery Systems

The following are primarily focused on the Air Defense Artillery Mission Area.

Masked Targeting (MT) Technology Demonstration (98-00). MT will demonstrate technologies and systems to support future air superiority and defense requirements. The MT concept encompasses sensors and weapons that address both line-of-sight (LOS) and terrain masked threats. MT will demonstrate a ground-based, organic sensor for direct targeting and a sensor payload for tactical unmanned air vehicles to provide targeting for indirect fire systems. This system will provide the maneuver force air defender with organic automated target detection, acquisition, ID, and ranging information. **Supports:** BSFV-E (Linebacker) and future missile systems.

2.75-Inch Anti-Air Technology Demonstration (97-99). The objective of the 2.75-Inch Anti-Air TD is to provide a comprehensive upgrade to the Stinger missile system through the incorporation of an advanced imaging infrared seeker to enable the engagement of hostile helicopters in clutter at extended ranges (2–3x). This demonstration will go beyond the current concept development program of a form factored seeker with commercial breadboard-type signal processing electronics to demonstrate the ability to package the signal processing electronics in 2.75-inch diameter. In addition, signal processing algorithms for target detection, tracking, and IR counter countermeasures will be developed and demonstrated via hardware in the loop simulations, ground tests, and captive carry tests. This system will maintain compatibility with existing Stinger launchers and retain Stinger's excellent capability against fixed-wing aircraft. **Supports:** FAAD Stinger Block II and all launch platforms.

Ducted Rocket Engine (DRE) Technology Demonstration (96-98). This TD is discussed in detail in *Fire Support*, Section N.

Future Missile Technology Integration (FMTI) Technology Demonstration (94-98). This technology demonstration is discussed in detail in *Aviation*, Section D.

Compact Kinetic Energy Missile (CKEM) Technology Demonstration (96-99). This technology is discussed in detail in *Mounted Forces*, Section G.

High Mobility Ground-Launched AIM-120 Advanced Medium Range Air-to-Air Missile (AMRAAM) Technology Demonstration (HMGL-AMRAAM) (96-99). The primary focus for this technology demonstration will lead to a low cost, highly mobile air and cruise missile defense capability based on the robust capabilities of the Joint Air Force/Navy/USMC AIM-120 AMRAAM missile. This concept will integrate this extremely capable digital fire-and-forget missile onto a highly mobile Avenger-based heavy HMMWV ground launch platform. Cueing for the systems will be provided by the AN/MPQ-64 Ground-Based Sensor (GBS) (or any other three-dimensional sensor) and remote fire control will be managed with the Simplified Hand Held Terminal Unit (SHTU). The AIM-120 AMRAAM launched from a HMMWV-based system provides medium range, high rate of fire missile with the multiple simultaneous target engagement capabilities needed to fill the gap between Stinger and Patriot. The mix of short (Stinger) and medium (AIM-120) range missiles will provide both the IR and RF guidance and homing needed to counter the evolving Cruise Missile and UAV threats. **Supports:** AIM-120 AMRAAM, RFPI ACTD, Current and Future Missile Systems.

Electronic Integrated Sensor Suite for Air Defense (EISS-AD) (94-97). The EISS-AD is a Joint Service (Army/Navy) effort designed to address known Combined Arms FAAD capability deficiencies. It will demonstrate a survivable air defense system for rapid insertion forces (U.S. Marine Corps) and close combat heavy forces (U.S. Army). The objective is to demonstrate an integrated sensor suite that provides automated target acquisition, tracking, and identification of aircraft in an operational air defense environment at standoff range. In addition, an on-the-move capability will be demonstrated. This demonstration will consist of the integration of state-of-the-art electronic sensors to include an improved Infrared Search and Track Capability (IRST), target confirmation hardware with special processing Noncooperative Target Recognition (NCTR) technologies, and eye safe laser rangefinder (LRF). **Supports:** BSFV-E (Linebacker), Corps SAM.

Guidance Integrated Fuzing (95-97). The objective of Guidance Integrated Fuzing is to develop and demonstrate guidance integrated fuzing techniques for millimeter wave active homing seeker systems in air defense missiles, utilizing a mix of target signature measurements, target backscatter modeling, and endgame modeling. This effort will also provide algorithms for integrated guidance and fuzing to track high speed targets from the munition to achieve accuracy for warhead kills. In addition, near-far field target signatures from millimeter wave, monopulse instrumentation radar will be collected. It is expected that this effort will generate high fidelity target models to support highly accurate guidance integrated fuzing simulations to validate robust system designs. **Supports:** Patriot Advanced Capability (PAC3), Corps Surface-to-Air Missile (Corps SAM).

Armicide Technology Demonstration (97-00). The Armicide Tech Demo will demonstrate a concept designed to serve as an adjunct for Anti-Radiation Missile (ARM) defense to the major air defense systems such as Patriot and the THAAD Ground-Based Radar (GBR). Armicide will use the organic air defense system radars to provide the fire control to engage the ARM target. Thus the need for providing an expensive counterarm sensor is avoided. Armicide consists of the following main components which are currently within the realm of engineering implementation, or available with minor modifications: (1) a medium caliber command guided smart munition which does not require an expensive homing seeker; (2) two rapid fire conventional launchers, whose design and technology are in use by all Services, as well as internationally; (3) a fire control processor/transmitter; and (4) the host radar (Patriot and GBR) that will provide target and interceptor tracking information to the fire control unit. This function will be discussed at a later time and will not impact the normal mission function of the radar. **Supports:** Patriot, THAAD GBR.

c. Benefits to Air Defense Artillery Systems

Benefits to the air defense mission area that may be derived from ATDs, STOs, and Advanced Concepts are as follows:

- New search and track capabilities which could be adapted into air defense's multi-sensor capabilities.
- Improved integration of sensors and fire control systems providing faster "slew-to-cue" capabilities for air defense weapons.
- Propellant and guidance movements that may be incorporated into air defense weapons to provide dead zone and self-protection coverage.
- Combat identification enhancements to ensure higher accuracy of positive identification of hostile and friendly targets, therefore reducing possibility of fratricide.
- Communication enhancements improving the vertical and horizontal sharing of critical battlefield information and increasing the accuracy and volume of data being shared.
- Survivability enhancements that will lower the susceptibility of air defense sensors to ARMs and will decrease existing air defense systems vulnerability to indirect fire.
- Fuzing improvements that will lead to higher probability of kills of both conventional targets and weapons of mass destruction.
- Digitization of the battlefield.

5. Relationship to Modernization Plan Annexes

It is important that Air Defense Artillery modernization and related technology base program efforts exhibit a linkage with Army Modernization Plan Annexes in other mission areas. This linkage is important for decision makers when prioritizing all of the Army's modernization efforts. Figure III-L-2 portrays the linkage of Air Defense Artillery S/SU/ACs and other Army Modernization Plan Annexes.

Figure III-L-2. Correlation Between Air Defense Artillery S/SU/ACs and Other Army Modernization Plan Annexes

MODERNIZATION PLAN ANNEXES

AIR DEFENSE ARTILLERY

SYSTEMS/SYSTEM UPGRADES/ADVANCED CONCEPTS

		Aviation	IEW	Close Combat Light	C4	Mounted Forces	TMD
System	Corps SAM	O	O		O		●
System Upgrades	Patriot PAC-3		O		O		●
	Bradley Stinger Fighting Vehicle–Enhanced (Linebacker)				O	●	O
Advanced Concept	Stinger Block II	O		O	O		O

● System plays a significant role in the Modernization Strategy.

O System makes a contribution to the Modernization Strategy.

M. Engineer and Mine Warfare

Have you ever been in a minefield? ...All there has to be is one mine and that's intense.

Gen. H. Norman Schwarzkopf

1. Introduction

The U.S. Army is facing a changing threat with varied degrees of sophistication as it enters the 21st century. Given this uncertain threat, the Engineer and Mine Warfare (EMW) mission area continues to play a key role as a critical member of the Combined Arms Team. Recent military operations have demonstrated the critical need for a robust EMW mission area which is vital to the Combined Arms Team and Combat Service Support Elements being able to fulfill their future military role.

The EMW mission area consists of the five major battlefield functions of mobility, countermobility, survivability, sustainment engineering, and topographic engineering. Each function is critical to conducting successful operations throughout the operational continuum, whether fighting a major regional conflict or providing military assistance in operations other than war. Applying technological advancements to modernize these functions enhances the combined arms commander's ability to conduct opposed entry, sustained land combat, and operations other than war to achieve a decisive victory. This section focuses on funded EMW science and technology (S&T) programs which provide systems and system upgrades (S/SUs) in support of Combat Maneuver modernization. Only systems and system upgrades identified in the Combat Maneuver Annex to the *Army Modernization Plan* (AMP), of which EMW is a part, and advanced concepts with planned 6.3 technology demonstrations of potential future systems are addressed in this section.

2. Relationship to Operational Capabilities

Table III-M-1 shows the relationship between the EMW S/SUs and each of the TRADOC Battlefield Dynamics. It also details some of the operational capabilities provided by these S/SUs.

3. Modernization Strategy

The Combat Maneuver Annex to the AMP provides the blueprint for equipping engineer forces into the next century. It embraces the Army's Modernization Vision—**LAND FORCE DOMINANCE**—by contributing to the five Army modernization objectives.

Project and Sustain: The assessment and construction or reconstruction of ports, airfields, roads, and other infrastructure to rapidly and consistently project forces and maintain logistical forces.

Protect the Force: Construction of structures to protect critical command and control, weapon systems, and logistics nodes by camouflage, concealment or bunkerage.

Win the Information War: Provide engineer-related force level information, standard hard copy and digital maps, map substitute imagery, battlefield visualization products, and other types of terrain data give commanders a realistic view of the battlefield. Information and products must be readily available, rapidly updated, and quickly manipulated or tailored. Real-time electronic distribution to all elements of the force will increase leader battlefield awareness and allow commanders to operate inside their opponent's decision cycle.

Conduct Precision Strike: Utilization of accurate electronic terrain data for display and tactical exploitation to obtain precise location data of both the target and the shooter. Engineer assessment of conventional weapons effects against hard structural targets will ensure correct munition-to-target linkage. This will lead to improved effectiveness and precision of weapon system fires and total dominance of the deep battle.

Table III-M-1. Engineer and Mine Warfare Capabilities

S/SU FUNCTION	Early Entry (BATTLEFIELD DYNAMICS)	Depth and Simultaneous Attack	Mounted Battlespace	Dismounted Battlespace	Battle Command	Combat Service Support	SYSTEM/SYSTEM UPGRADE CAPABILITIES	ADVANCED CONCEPT CAPABILITIES
MOBILITY								
Systems Ground Standoff Mine Detection System	●	●	●	○		●	• Advanced image processing • Real time data transfer • Detection for heavy and light forces • Teleoperation capability • Advanced IR for standoff capability	
Mine Hunter Killer	●	●	●	○		●	• Smart mine neutralization focusing on side attack • Detection for light and special operations forces • Combined detection and neutralization capability • Teleoperation capability • Unexploded ordnance detection • Rapid breaching and mine UXO clearance	
COUNTERMOBILITY								
Systems Intelligent Minefield	●	●	●	●	●	●	• Integration of smart wide area mines, comm links, sensor data, and battlefield management software	
SURVIVABILITY								
Systems Upgrades Low Cost, Low Observable Technologies	●	●	●	●	●	●	• Improved visual, IR, and radar signature suppression • Low cost mobile signature suppression • Improved chemical agent resistant coating • IR suppressive coating • Integrated active-passive signature control in UV, visible IR, and RF bands • Tunable countermeasures	
TOPOGRAPHIC ENGINEERING								
System Upgrades Digital Topographic Support System (DTSS)/Quick Response Multicolor Printer	●	●	●	●	●	●	• Rapid map or map substitute products • Battlefield environmental effects • Real-time creation, update, and dissemination of digital topographic data bases • Integrated decision aids	

● Provides Significant Capability ○ Provides Some Capability

Dominate the Maneuver Battle: Enhancing the tactical mobility of friendly maneuver forces and impeding the mobility of threat forces to provide commanders both protection and maneuverability necessary to dominate battlespace.

The EMW modernization strategy relies on continuous modernization as a key concept. The acquisition approach emphasizes investment in S&T programs leading to Advanced Technology Demonstrations (ATDs), targets of opportunity, Battle Lab Experiments, Advanced Warfighting Experiments and the Joint Countermine Advanced Concept Technology Demonstration. Technological advances will be incorporated more often into systems via upgrades versus entirely new systems.

Of the EMW battlefield mission areas, mobility and survivability are currently receiving a new focus in S&T due to the ever increasing mine threat. Effective and responsible mine warfare obstructs the mobility and survivability of opposing forces and creates conditions favorable to the mine employer without inflicting needless casualties on noncombatants. Mine warfare constitutes a significant element in armed conflict at all levels of intensity and is critical to early entry forces who may be overmatched. The Intelligent Minefield (IMF) ATD will enhance the antiarmor lethality of the early entry force, cue fires beyond line-of-sight, and provide the potential to revolutionize maneuver. IMF can not only be turned off to provide one-way obstacles, but should be able to augment friendly maneuver forces by performing screen and guard missions autonomously. Mines are cheap, lethal, psychologically disruptive, and readily available, and they will be encountered on all future battlefields. The result is that relatively cheap mines employed quickly and in quantity can immobilize a powerful force.

Mine improvements will likely continue at a rapid pace. Inexpensive, land mines can destroy multi-million dollar weapon systems. The future outlook is even more ominous, with the evolution of new smart mines. Microelectronics will soon take mines to new levels of lethality. The countermine shortfall is particularly worrisome because it strikes at the heart of Army's doctrine of rapid movement and surprise to win quick decisive victories. The S&T and acquisition community are totally committed to solving and fielding equipment by providing adequate resources and support.

Joint Countermine Advanced Concept Technology Demonstration (CM ACTD) (95-00). This ACTD will demonstrate a seamless amphibious and land warfare countermine operational capability from sea to land by coordinating Army, Navy, and Marine Corps technology demonstrators, prototypes, and fielded military equipment.

Demonstration I, planned for FY97, focuses on near-shore capabilities of assault, reconnaissance, breaching, and clearing with emphasis on in-stride detection and neutralization of mines and obstacles. The Army is lead for Demonstration I. It includes joint Army/Marine Corps technology demonstrations in mine detection technology for the Army's future close-in manportable mine detector, with the capability to detect both metallic and non-metallic mines (Handheld Standoff Mine Detection System, Vehicular Mounted Mine Detector ATD); and countermeasures to side attack mines (Off-Route Smart Mine Clearance) in support of conventional minefield breaching and clearing operations. These technologies are applicable to other military uses such as unexploded ordnance and range clearing, duds on the battlefield, and demining.

Demonstration II, planned for FY98, will emphasize technologies of clandestine surveillance and reconnaissance as described in the FY94 Navy Mine Warfare Plan and will demonstrate the elements of seamless transition of countermine operations from sea to land. The Navy is lead for Demonstration II.

4. Engineer and Mine Warfare Roadmaps

Table III-M-2 presents a summary of the S/SU, Technology Demonstrations, and ATDs found in the EMW roadmaps shown in Figure III-M-1.

a. Mobility

Engineers enhance friendly freedom of maneuver by defeating, bypassing, breaching, marking, and reporting mines and other obstacles, crossing gaps, providing combat roads and trails, and performing Forward Aviation Combat Engineering (FACE) operations. S&T programs focus on integrating countermine capabilities

Table III-M-2. Engineer and Mine Warfare Demonstration and System Summary

ATDs / ACTD	TECHNOLOGY DEMONSTRATIONS
ATDs • Intelligent Minefield • Hunter Sensor Suite (see *CCL,* Section H) • Vehicular Mounted Mine Detector • Mine Hunter Killer **ACTD** • Joint Countermine • Rapid Battlefield Visualization (see *IEW,* Section F) (For additional information, see Volume II, Annex B.)	**Countermobility** • Mobility and Survivability (Battle Command) **Survivability** • Low Cost, Low Observable (LCLO) • Lightweight, Airborne Multispectral Countermine Detection System **Topographic Engineering** • Integrated Terrain Data and Imagery

SYSTEMS/SYSTEM UPGRADES

Systems	*System Upgrades*
• Ground Standoff Mine Detection System • Intelligent Minefield • Mine Hunter Killer	• Digital Topographic Support System/Quick Response Multicolor Printer • Low Cost, Low Observable Technologies

through live and simulated experiments, maintaining Army and Marine Corps enhanced mobility, survivability, situational awareness, and agility to the force commander as a result of integrating countermine technology with C4I. The pacing technologies include sensor IR, microwave, multispectral, seismic and acoustic decoys, explosive neutralization, information processing, robotics, and other emerging technologies.

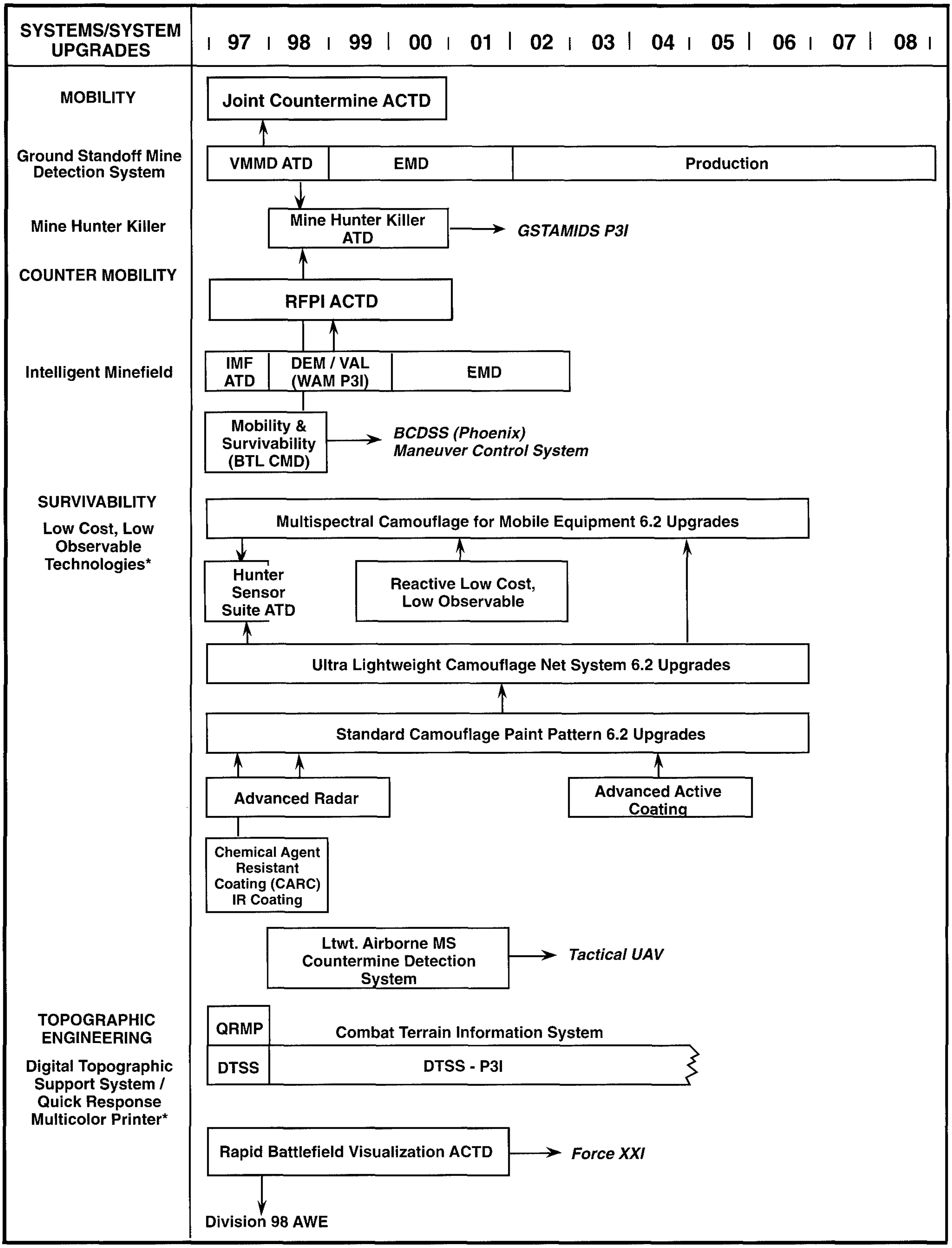
Vehicular Mounted Mine Detector ATD (96-98). The vehicular detector will demonstrate the mounted capability to detect metallic and nonmetallic mines, conventionally or remotely emplaced. The system will consist of a detection array located on the front of host vehicles, an operator screen display, a data interpretation algorithm, and a power source. Ground-penetrating radar, forward-looking radar, infrared, sensor fusion, automatic target recognition, and teleoperation capability will be demonstrated. Two multisensor suites for mounted, close-in, and stand-off detection of minefields, individual mines, and unexploded ordnance are planned. **Supports:** Joint Countermine ACTD and Ground Standoff Mine Detection System.

Mine Hunter Killer ATD (98-00). This program will demonstrate a countermine system that will be effective against a wide variety of antitank and antipersonnel metallic and nonmetallic mines. It will show an integrated countermine system employing infrared detection, forward-looking radar, and neutralizing technologies. This integrated system will demonstrate the ability to detect and kill mines and unexploded ordnance at a standoff distance while on the move. The vehicle will be outfitted with low cost, low observable technology to improve its survivability in forward deployed areas. **Supports:** Mine Hunter Killer and Ground Standoff Mine Detection System P3I.

b. Countermobility

Engineers impede the enemy's freedom of maneuver by disrupting, turning, fixing, and/or blocking his movement through obstacle development and terrain enhancement. S&T programs are integrating microelectronics, signal processing, and advanced intelligence into a controlled network of mine warfare systems. Minefields now consist of an array of independent mines, each with a preprogrammed response to an encroaching target. The Intelligent Minefield (IMF) transforms this independent array into a coordinated combat network with a gateway that transmits commands to and receives data from each mine. This gateway is linked or relayed to a remote control station in the maneuver headquarters. This network provides the commander with real-time targeting data from the minefield array. An on/off/on capability provides friendly forces freedom of maneuver and reduces the cost and logistical

Figure III-M-1. Roadmap for EMW Modernization



* System Upgrades

burden by permitting recovery/repositioning of mines. The goal is a mine system that can defend terrain, employing direct fire tactics, without overwatching direct fires, thus providing an economy of force, survivability, and greater lethality important to early entry forces.

Intelligent Minefield (IMF) ATD (93-97). This ATD will demonstrate breadboard hardware of key elements such as controllers and associated software, communications links, advanced on/off/on safe and arm devices, and extended range sensors. The goal is to demonstrate basic feasibility of coordinated tactics and remote control/reporting by integrating with the existing Wide Area Munition (WAM) program. The ATD will also provide hand-emplaced acoustic sensors for the Rapid Force Projection Initiative (RFPI) ACTD, detailed in Section H, *Close Combat Light*. **Supports:** WAM P3I and RFPI ACTD.

Mobility and Survivability (Battle Command) (95-98). This program will demonstrate decision support applications for mobility, countermobility, and survivability force level information that supports multiple battlefield operating systems. Physics-based algorithms, applicable to all climatic regions, that automate the engineer's efforts to filter, assess, and manipulate data into relevant information for the maneuver commander and staff will be incorporated into obstacle planning software and simplified survivability assessments that will be demonstrated during Task Force XXI AWE and Division XXI exercises. The software suite to be demonstrated will also provide the engineer commander with the ability to execute engineer domain force level command and control. **Supports:** Battle Command Decision Support System (BCDSS) (Phoenix), Maneuver Control System (MCS).

c. Survivability

Engineers reduce friendly force vulnerability to enemy weapon effects through rapid fabrication of protective structures, terrain alteration, and concealment. S&T programs are focused on upgrades to the low cost, low observable (LCLO) camouflage systems. These systems provide means for detection and hit avoidance. The upgrades are designed to reduce or eliminate visual, ultraviolet, near infrared (NIR), thermal IR, and radar waveband signatures of mobile and stationary assets. The goal is to counter the highly sensitive reconnaissance, intelligence, surveillance, target acquisition (RISTA) threat sensors, and fused sensors in all parts of the electromagnetic spectrum. Signature control will be achieved through integration of passive, reactive, and active low observable systems.

Field fortifications research is conducted by the Corps of Engineers' Waterways Experiment Station (WES) for all of DoD. The focus of these efforts is in design of protective structures to defeat advanced munitions (bunker busters) and unconventional munitions (car bombs), to capture commercial technology, and to identify high payoff protection techniques.

Low Cost, Low Observable (LCLO) System Upgrade Demonstrations (94-06). Demonstrations are scheduled during FY94-FY00 for upgrades to LCLO systems, including the Ultra Lightweight Camouflage Net System—General Purpose (ULCANS-GP), Multispectral Camouflage System for Mobile Equipment, and Reactive/Active Standardized Camouflage Paint Pattern (SCAPP). Currently fielded LCLO systems do not counter threat thermal infrared sensors. **Supports:** Ultra Lightweight Camouflage Net System, Multispectral Camouflage System for Mobile Equipment, Standard Camouflage Paint Pattern.

Lightweight Airborne Multispectral Countermine Detection System Technology Demonstration (98-01). This demonstration will utilize novel focal plane array (FPA) and system technologies (3–5 μm staring FPAs, passive polarization, multi/hyperspectral imaging, electronic stabilization) to develop a lightweight airborne standoff mine detection capability for limited area (point) detection, limited corridor route reconnaissance, and detection of nuisance mines along roads. The system will detect buried nuisance mines on unpaved roads and off-route side attack mines, as well as detection of surface and buried patterned and scatterable minefields. The system will also have applications to other intelligence gathering programs requiring increased thermal sensitivity as well as those that would benefit from a wider field of view than supported by a framing FLIR. **Supports:** Tactical UAV.

Hunter Sensor Suite ATD (94-97). Low observable ("cheap suit") technologies are being incorporated into the Hunter Sensor Vehicle.

See *Close Combat Light*, Section H, for further details.

d. Sustainment Engineering

Engineers support force sustainment by maintaining, upgrading, or constructing lines of communication and facilities; providing construction support and materials; and performing area damage assessment. Sustainment in the form of infrastructure assessment, generation and allocation of engineer resources required, and visualization technologies will be among the technologies critical in wartime contingency and support and sustainment operations. Chapter IV, Section L, *Civil Engineering and Environmental Quality*, provides more information on sustainment engineering S&T efforts.

e. Topographic Engineering

Topographic engineers provide timely, accurate knowledge of the battlefield and terrain visualization to operational commanders and staffs at all echelons throughout the operational continuum. Knowledge of the battlefield consists of information in narrative or graphic format describing the effects of terrain and climate on military operations. The ability of the commander to visualize the terrain in all climate conditions before the battle will help him to develop dynamic operational plans; and locate, engage, and defeat the enemy with a more agile, synchronized force. Terrain information developed by Army engineers provide the basic terrain reference for land and air forces as well as other DoD and non-DoD agencies.

S&T programs focus on providing tactical environmental decision support, real-time position and azimuth determination, realistic battlefield visualization capabilities, terrain data base construction and/or update, data base value-adding for modeling and simulation, and geographic data base management. In addition, key to battlefield awareness and crisis response is the development of technologies to support the capability for the rapid production and dissemination of image-based topographic products. Advances in microelectronics, artificial intelligence, advanced computing, and signal processing techniques make topographic technology an extremely dynamic field.

Topographic engineers are working closely with TRADOC Battle Labs and the user community to demonstrate, evaluate, and refine technological developments and doctrinal topographic support concepts. Initial fielding of the Combat Terrain Information System [Digital Topographic Support System (DTSS), and the Quick Response Multicolor Printer (QRMP)], coupled with its accelerated Preplanned Product Improvement (P3I) program directed at imagery exploitation, will provide the battlefield commander with the latest in topographic technology.

Rapid Battlefield Visualization (Proposed) ACTD (97-01). This ACTD will demonstrate capabilities to rapidly collect source data and generate high resolution digital terrain data bases to support crisis response and force projection operations. It will demonstrate capabilities for the commander to integrate these terrain data bases with current situation data, and manipulate and display the integrated data bases to visualize a desired end state. (See Section III-F, *IEW*, for more detailed information.) **Supports:** Force XXI, Division '98 AWE.

5. Relationship to Army Modernization Plan Annexes

The EMW modernization strategy and related S&T programs are linked with Modernization Plans in other mission areas. Figure III-M-2 shows the linkage between EMW S/SUs and other Army Modernization Plan Annexes.

Figure III-M-2. Correlation Between Engineer and Mine Warfare S/SUs and Other Army Modernization Plan Annexes

ENGINEER AND MINE WARFARE SYSTEMS/SYSTEM UPGRADES		Mounted Forces	Close Combat Light	Air Defense Artillery	IEW	Soldier Systems	C4	Aviation	Fire Support
Systems	Vehicular Mounted Mine Detector	○	○						
	Intelligent Minefield	○	○	○	●		○		○
	Mine Hunter Killer	●	○			○			
System Upgrades	Digital Topographic Support System/Quick Response Multicolor Printer	●	●	○	●		●	○	○
	Low Cost Low Observable Technologies	●	○	○	○		○	○	

MODERNIZATION PLAN ANNEXES

● System plays a significant role in the Modernization Strategy.

○ System makes a contribution to the Modernization Strategy.

N. Fire Support

The artillery must be prepared to concentrate a great volume of fire wherever it is needed, at any moment, so as to dominate rapidly any part of the battlefield which might be threatened.

General Charles DeGaulle
"The Army of the Future," 1941

1. Introduction

Fire support is the collective and coordinated use of indirect fires, target acquisition data, armed aircraft, and other lethal and nonlethal means against ground targets in support of maneuver force operations. The mission of fire support is to destroy, neutralize, or suppress the enemy with indirect fires and integrate all available means of fire support.

Fire Support responsibilities focus on close support fires in support of engaging maneuver units, counterfire (the attack of enemy indirect fire support systems), and interdiction (the attack of enemy laterally and in-depth). It includes artillery, mortars, other non-line-of-sight weapons, Army aviation, naval gun fire, close air support, and electronic countermeasures.

2. Relationship to Operational Capabilities

To achieve the required operational capabilities, the Fire Support Systems/System Upgrades and Advanced Concepts (S/SU/ACs) will provide unique system capabilities that will enhance the commander's ability to meet the ever dynamic requirements of the battlefield. Fire Support capabilities include: supporting the ability of early entry operations to rapidly deploy to and secure the operational area; providing critical elements of the combat power required to defeat an enemy throughout the depth of the battlefield; supporting the commander's requirement to control the rate and pace of combat activities; supporting critical aspects of the commander's ability to effect operations against opposing forces engaged in combat actions; and providing essential capabilities in the logistics spectrum to support, rearm, and resupply fire support assets required to sustain the soldier on the battlefield (see Table III-N-1).

3. Modernization Strategy

The Army Modernization Plan Fire Support Annex provides the direction and focus of our modernization strategy. The cornerstone for the successful implementation of this continuous modernization strategy is our science and technology programs. These programs will focus on system upgrades, new systems, and advanced concepts that will provide quality materiel to commanders that ensure their ability to "fight fires with fire."

4. Fire Support Roadmap

Table III-N-2 presents a summary of ACTDs, ATDs, and major technology demonstrations leading to systems development and upgrade. Modernization of the fire support operating system depends upon the development of these key systems for fire support coordination, close support, counterfire, command and control, and target acquisition, as well as munitions and rockets, and their ultimate fielding as a fire support system of systems.

As shown in Figure III-N-1, S&T efforts focus on:

- Maximization of kill capability
- Advanced gun/rocket propulsion
- Automated ammunition handling
- Integrated fire control and battle management
- Signature reduction and increased protection
- Classification, tracking, and identification of ground vehicles
- Sensors (acoustic and electro-optical) and processing
- AI and computing technologies
- Increased battlefield operational mobility

Table III-N-1. Fire Support System Capabilities

S/SU/AC FUNCTION	BATTLEFIELD DYNAMICS: Early Entry	Depth and Simultaneous Attack	Mounted Battlespace	Dismounted Battlespace	Battle Command	Combat Service Support	SYSTEM/SYSTEM UPGRADE CAPABILITIES	ADVANCED CONCEPT CAPABILITIES
RANGE								
System								
Crusader		●	●		●		• Deep fire—20 to 40 km beyond FLOT	
Lt.Wt. 155mm Towed Howitzer	●	○		○			• 54% increase in on-board ammo (60 vs 39 Paladin)	
System Upgrade							• Decision aids	
ERA Projectile - XM982	●	●	●				• 155mm range from a lightweight system	
Advanced Concept								
HICAP	●	●	○	●				• Increased range and/or cargo capacity
Guided MLRS	●	●	○					
LETHALITY								
Systems								
Crusader		●	●		●	●	• Increased rate of fire (12-16 rds/sec)	
Lt.Wt. 155mm Towed Howitzer	●	○					• Point target accuracy	• Mobile long-range capability
System Upgrades							• Robotic and automated rapid ammo handling	• Reduced logistics burden • RF energy
Multimode Airframe Technology	●	●	○	○			• Increased lethality area	• IFF
ERA Projectile – XM982	○	●	●				• 155mm firepower from a lightweight system	• Top attack surgical kill • Increased footprint covers moving targets
Advanced Concepts								
Guided MLRS	●	●				●		• Improved response time
PGMM	●	○	●	●				• Increased range with self-destructive cargo
AIS/Damocles	●	●	○					
155mm AH	●	●		●	●			• Precision guidance capability
ACCURACY								
Systems								
Crusader		●	●				• Deep fire—20 to 40 km beyond FLOT	
Lt. Wt. 155mm Towed Howitzer	○	○					• On-board sensors • On-board target acquisition	
System Upgrades							• Increased sensor accuracy	
Fire Finder P3I		●	●		●		• Increased mobility	
Multimode Airframe Technology	●	●	○	○			• Munitions classification	• Improved delivery accuracy
ERA Projectile - XM982	●	●	●	●			• Decision aids • Improved navigation • Point target capability at long ranges	• Manportable fire control • Top attack surgical kill for U.S. Infantry
Advanced Concepts								• GPS auto-registration or auto self correcting
Precision Guided Mortar Munition	●		●	●				
Guided MLRS	●	●	○		●			• Improved targeting
155mm AH	●	●						• Precision guidance capability

● Provides Significant Capability ○ Provides Some Capability

(Continued)

Table III-N-1. Fire Support System Capabilities (Continued)

S/SU/AC FUNCTION	BATTLEFIELD DYNAMICS: Early Entry	Depth and Simultaneous Attack	Mounted Battlespace	Dismounted Battlespace	Battle Command	Combat Service Support	SYSTEM/SYSTEM UPGRADE CAPABILITIES	ADVANCED CONCEPT CAPABILITIES
SURVIVABILITY								
System								
Crusader		●	●				• Autonomous • Real time on target met data • Decision aids • 155mm range firepower and area coverage with lightweight mobility	
Lt.Wt. 155mm Towed Howitzer	●	○						
System Upgrades								
Fire Finder P3I	○	●	○	○	●		• Doubles range • 250% greater survivability • Smart weapon ECCM • Improved mobility • Data link to TMD	
Advanced Concepts								
Guided MLRS	●	●				●		• Reduced time at firing point • Novel (non-volatile) propellants • Improved ECCM • Rapid deployment • Route planning and self-defense AI modules • Launch to digitized battlefield • Fire-and-forget
155mm AH	○	●	○					
Decision Aids for Advanced Artillery/Armament Decision Aids		●	●					
FORCE MULTIPLIER								
Systems								
Crusader		●	●		●		• Based on increased accuracy • Less manpower • Commonality of spares • Affordable long-range navigation • 155mm fire power for light forces • Smart Weapons • Extended range cargo delivery • Increased lethality • Smart Weapons	
Lt.Wt. 155mm Towed Howitzer	●	○		●				
System Upgrade								
ERA Projectile XM982	●	●	○	○				
Fire Finder P3I	○	●	○	○	●			
Advanced Concepts								
Guided MLRS	●	●				●		• Extended range cargo delivery (40-70 km) • AI • IFF • RF energy • Digitized 155mm firepower • Increased autonomous footprint • Autonomous or surgical kill for infantry
155mm AH	●	●	○					
AIS/Damocles	○	●	○					
PGMM	●		●	●				
MOBILITY								
Systems								
Crusader		●	●		●		• Composite technology • Autonomous operation • Land, water, air movement • On-board navigation	
Lt.Wt. 155mm Towed Howitzer	●	○		●				

● Provides Significant Capability ○ Provides Some Capability

Table III-N-2. Fire Support Demonstration and System Summary

ATDs	TECHNOLOGY DEMONSTRATIONS
• Precision Guided Mortar Munition (PGMM) (See Close Combat Light) • Guided MLRS • Indirect Precision Fire **ACTDs** • JPSD Precision/Rapid Counter MRL • Rapid Force Projection Initiative (RFPI) (see Close Combat Light) (For additional information, see Volume II, Annex B.)	• Decision Aids for Advanced Artillery/Armament Decision Aids • 155mm Automated Howitzer (AH) • Ducted Rocket Engine (DRE) • Autonomous Intelligent Submunition (AIS) • 105mm Terminally Guided Projectile (105 TGP) • Advanced Extended Range Cargo Projectile (AERCAP) • Multimode Airframe Technology

SYSTEMS/SYSTEM UPGRADES/ADVANCED CONCEPTS	
Systems • Crusader • Lt.Wt. 155mm Towed Howitzer ***System Upgrade*** • FireFinder P3I • Multimode Airframe Technology • Extended Range Artillery (ERA) Projectile – XM982	***Advanced Concepts*** • Precision Guided Mortar Munition (PGMM) • 155mm Automated Howitzer (AH) • Guided MLRS • Autonomous Intelligent Submunition (AIS)/ Damocles • Decision Aids for Advanced Artillery/Armament Decision Aids • High Capacity Artillery Projectile (HICAP)

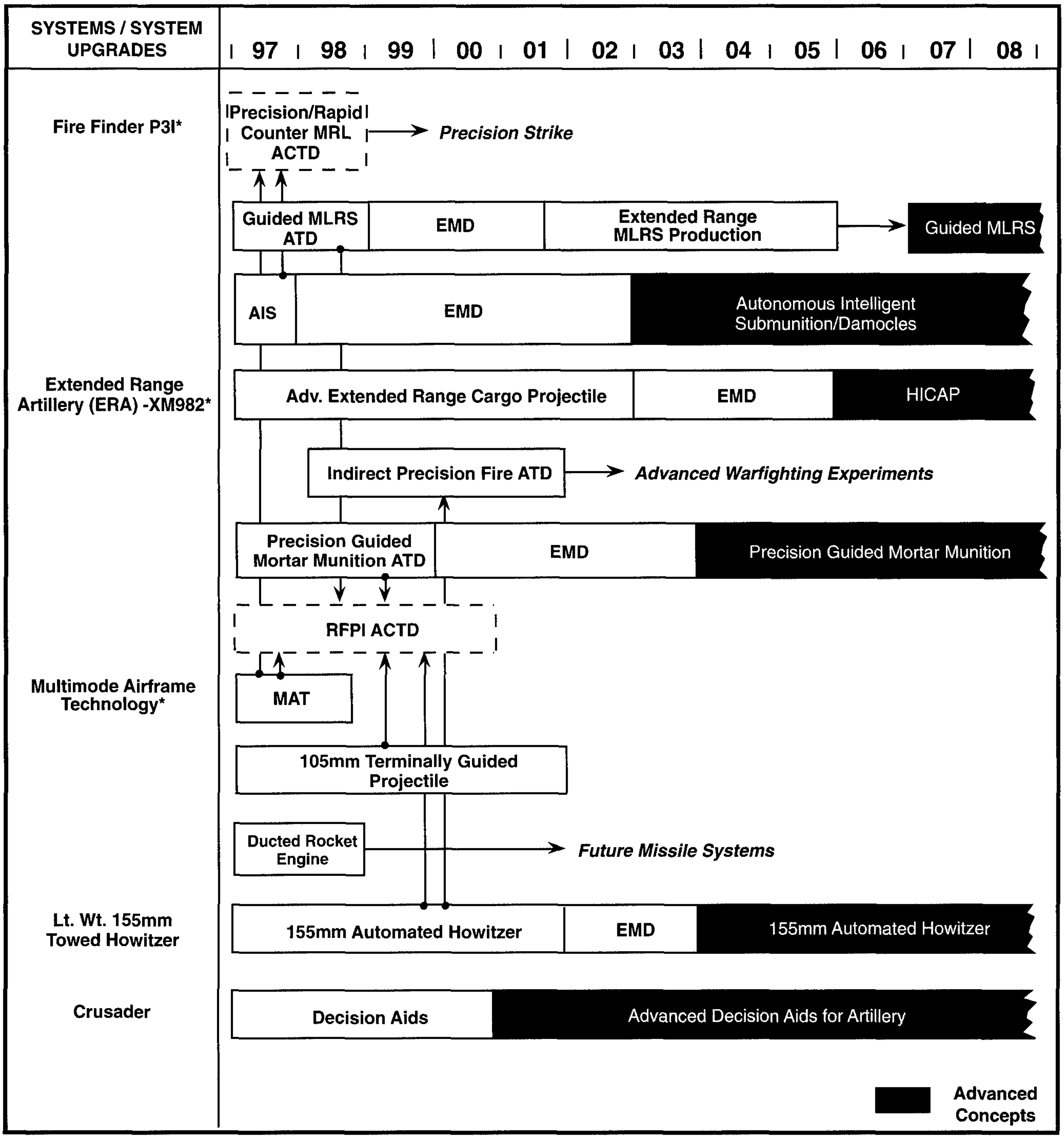
a. ATDs and Other Technology Demonstrations

Guided Multiple Launch Rocket System (MLRS) ATD (95-98). This ATD will demonstrate a significant improvement in the range and accuracy of the MLRS free-flight artillery rocket. Improved accuracy results in a significant reduction in the number of rockets required to defeat the target (as much as sixfold at extended ranges). Other benefits include an associated reduction in the logistics burden (transportation of rockets), reduced chances of collateral damage and fratricide, reduced mission times (resulting in increased system survivability), and increased effective range for the MLRS rocket. The ATD will design, fabricate, and flight-test a low cost guidance and control package to be housed in the nose of the rocket, thus minimizing the changes to the current rocket. A low cost Inertial Measurement Unit (IMU) coupled with a canard control system will be demonstrated in Phase I, followed by a GPS-aided IMU solution in Phase II. The IMU package will provide a 2–3 mil accuracy sufficient for some MLRS warheads with the GPS-aided package providing a 10-meter CEP accuracy for warheads which require precision accuracy. The package to be demonstrated will result in a rocket which is more cost effective and more lethal while requiring no change to crew training procedures or maintenance procedures (during the 15-year shelflife). The guidance and control package will be designed with applicability to bomblet, mine, precision guided submunition, and unitary/earth penetrator warheads. An EMD program is in the POM with an FY98 start. **Supports:** RFPI ACTD, Guided MLRS.

Precision Guided Mortar Munition (PGMM) ATD (94-99). The 120mm PGMM will demonstrate a multimission, multimode, precision munition capable of defeating high value point targets and light armored vehicles at extended ranges (12-15 km). Its modes of operation include autonomous fire-and-forget and/or laser designation for a surgical strike capability. **Supports:** RFPI ACTD 120mm mortars, Precision Guided Mortar Munition. See *Close Combat Light*, Section H, for details.

Autonomous Intelligent Submunition (AIS) Technology Demonstration (94-97). This demonstration will evaluate real-time performance of a state-of-the-art millimeter wave/IR sensor hardware for automatic acquisition and engagement of mobile and stationary high-value

Figure III-N-1. Roadmap for Fire Support Modernization



* System Upgrade

targets in realistic battlefield environments, various clutter, weather, and countermeasure conditions. **Supports:** RFPI ACTD and SADARM P3I.

Advanced Extended Range Cargo Projectile (AERCAP) Technology Demonstrations (95-02). These TDs will demonstrate both 155mm artillery and 120mm mortar projectile concepts which address conventional fire support needs for increased range delivery of cargo payloads. The 155mm Extended Range Artillery (ERA) Projectile - XM982 will deliver self-destructing Dual Purpose Improved Conventional Munitions (DPICM) cargo to extended ranges (40–70 km) and accuracy with LCCM by utilizing a hybrid rocket design. This design incorporates highly refined rear base-burn and front rocket technologies with a new streamlined configuration, cargo expulsion technique, accuracy enhancements, and imbedded fuzing into one cargo-carrying projectile. Additionally, research and experimentation is being conducted to deliver self-destructing DPICM cargo to extended ranges (12 km) from a 120mm composite mortar cartridge (ER-DPICM, XM984). The 12 km represents a 67 percent range increase and a 177 percent increase in area coverage. **Supports:** Precision Strike, High Capacity Artillery Projectile (HICAP), Depth and Simultaneous Attack and Dismounted Battlespace Battle Labs.

Indirect Precision Fire (IPF) ATD (96-01). This ATD will develop and demonstrate an auto-registration and guided competent munition, each miniaturized in a standard 155mm fuze package, to provide a revolutionary accuracy improvement. The effectiveness of all current and future artillery projectiles for all platforms will be improved, enabling first round fire for effect. The ATD will consist of two concept demonstrations: the auto-registration demonstration in FY98 and the guided competent munitions demonstration in FY01. These demonstrations will encompass a series of projectiles that will have the competent munitions modules screwed into the fuze well fired at different ranges. **Supports:** all existing and future 155mm munitions/platforms.

Rapid Force Projection Initiative (RFPI) ACTD (95-00). This ACTD will demonstrate a highly lethal, survivable, and rapidly air deployable enhancement to the Early Entry Task Force. It includes an automated Fire Control System (FCS) for selected Howitzers and the Enhanced Fiber Optic Guided Missile (EFOGM) non-line-of-sight weapon system. Further details are provided in *Close Combat Light*, Section III-H.

155mm Automated Howitzer (AH) Technology Demonstration (94-01). This program will demonstrate an automated, digital fire control system for a 155mm towed artillery system. The digital Fire Control System (FCS) has self location and direction determination. The FCS performs onboard, ballistic calculations that provide the system with greater responsiveness, accuracy, lethality, and survivablity. The advanced fire control technology supports the RFPI ACTD and subsequent ACTD. Automation such as self-location and direction determination, auto-rammer, and auto-primer loading are expected to increase efficiency, responsiveness, and accuracy. **Supports:** LW Howitzer Program and RFPI ACTD.

Decision Aids for Advanced Artillery and Armament Decision Aids Technology Demonstrations (94-00). The initial demonstrations evaluate a prototype decision-aid system for self-propelled artillery utilizing artificial intelligence and advanced computing techniques. The system consists of two decision aid modules, i.e., Reconnaissance, Selection, and Occupation of Position (RSOP) and Self Defense (SD). It will reduce planning time required for movement to a new fire position, decrease response time to a new mission, and increase self-survivability capability. The follow-on demonstration (Armament Decision Aids) will build upon previously developed technology and link the individual fire support platform to the digitized battlefield. This demonstration will alow individual or groups of fire support platforms to operate, as needed, outside of the traditional fire support command and control (C2) structure and fully exploit new plans, procedures, and tactics of the digital battlefield. Benefits will include improved situational awareness, synchronized movement with maneuver forces, and, ideally, fratricide avoidance. **Supports:** Crusader.

JPSD Precision/Rapid Counter MRL ACTD (95-98). This ACTD will demonstrate a significantly enhanced capability for U.S. Forces Korea (USFK) to neutralize the North Korean 240mm Multiple Rocket Launcher (MRL) system. Because of the brief time in which this target is expected to be exposed and vulnerable to counterfire, near-continuous surveillance and near-instantaneous target acquisition will be required as well as the employment of innovative target attack means. Smart munitions for the MLRS Family of Submunitions (MFOM) will be demonstrated through simulations in the ACTD to include smart munitions for increased effectiveness and coverage. Project management and funding will continue through FY98. **Supports:** Precision Strike.

Ducted Rocket Engine (DRE) Technology Demonstration (FY96-98). The Ducted Rocket Engine (DRE) program is a joint research and development effort with Japan to develop and demonstrate a ducted rocket engine for a medium surface-to-air missile which will significantly increase the intercept envelope against aircraft and cruise missiles when compared with surface-to-air missiles utilizing current solid rocket propulsion technology. It is the first developmental program under the auspices of the U.S. Department of Defense/Japan Defense Agency Systems and Technology Forum (S&TF). The component technology development and engine demonstration effort is focused on the design and testing of a minimum signature, insensitive munitions compatible booster, supersonic air inlets, and a solid fuel gas generator which provides for high impulse, minimum signature ramburner operation. Performance data acquired from the DRE program integrated tests may provide a basis for the design of a future, operationally deployable surface-to-air and/or long range surface-to-surface missile system. **Supports:** Future missile systems, Battle Comand, Depth and Simultaneous Attack and Early Entry Lethality and Survivability Battle Labs.

105mm Terminally Guided Projectile (TGP) Technology Demonstration (98-01). The 105 TGP program will demonstrate a precision guided artillery projectile with an autonomous fire-and-forget capability against armored targets and/or a laser designating capability for defeat of point targets (bunkers, buildings, high value targets). The 105 TGP munition will increase the lethality and survivability of the Light Forces by providing a new capability to existing 105mm weapon platforms. **Supports:** RFPI ACTD.

Multimode Airframe Technology (MAT) Technology Demonstration (95-98). This technology demonstration will provide the battlefield commander with a long range (40+ km) precision guided artillery weapon that will provide light forces surgical kill capacity against heavy armor, helicopter, and bunker targets. Further, it will provide extended range and precision terminal homing capabilities, enhanced survivability and lethality, jam-proof data link, and low-signature turbojet launch using GPS/IMU for navigation. **Supports:** RFPI ACTD, JPSD Precision/Rapid Counter MRL ACTD.

5. Relationship to Modernization Plan Annexes

Figure III-N-2 shows the correlation between the Fire Support S/SU/ACs and other Army Modernization Plan Annexes.

Figure III-N-2. Correlation Between Fire Support S/SU/ACs and Other Army Modernization Plan Annexes

FIRE SUPPORT
SYSTEMS/SYSTEM UPGRADES/ADVANCED CONCEPTS

MODERNIZATION PLAN ANNEXES

		Close Combat Light	Mounted Forces	IEW	Air Defense Artillery
Systems	Crusader	○	●		
	Lt.Wt. 155mm Towed Howitzer	●	●		
Systems Upgrades	FireFinder P3I	○	○	●	
	Multimode Airframe Technology	●			●
	Extended Range Artillery (ERA) Projectile - XM982	●	●		
Advanced Concepts	155mm Automated Howitzer (AH)	●	●		
	Precision Guided Mortar Munition (PGMM)	●	○		
	Guided MLRS	●			
	Autonomous Intelligent Submunition (AIS)/Damocles		○		
	Decision Aids for Advanced Artillery/Armament Decision Aids		●	○	
	High Capacity Artillery Projectile (HICAP)	●	○		

● System plays a significant role in the Modernization Strategy.

○ System makes a contribution to the Modernization Strategy Area.

O. Logistics

Logistics comprises the means and arrangements which work out the plans of strategy and tactics. Strategy decides where to act; logistics brings the troops to this point.

General Antoine Henri Jomini
Summary of the Art of War

1. Introduction

Logistics is the science of planning and carrying out the movement and maintenance of forces. In its most comprehensive sense, Army logistics encompasses those aspects of military operation that deal with:

- Design, development, acquisition, storage, survivability, movement, distribution, maintenance, evacuation, and disposition of materiel
- Sustainment, movement, evacuation, and hospitalization of personnel
- Acquisition and furnishing of services

The purpose of Logistics is to generate, mobilize, deploy, employ, provision, reconstitute, redeploy, and demobilize military forces. The realities of our new National Military Strategy and the changed threat necessitate a movement from a forward deployed Army to one of force projection. Consequently, logistics must now be able to rapidly project forces and sustain materiel to meet contingencies throughout the world and then provide for those forces over time. The efforts addressed in this section are only those that have plans for present or future science and technology efforts. Technology efforts that lead to individual soldier and combat health support modernization are discussed in Sections I and J, respectively, of this chapter.

2. Relationship to Operational Capabilities

Logistics Systems Upgrades and Advanced Concepts (SU/ACs) and their link to the TRADOC Battlefield Dynamics are shown in Table III-O-1. This table also displays the operational capabilities for each of the SU/ACs.

3. Logistics Modernization Strategy

The Logistics Annex of the Army Modernization Plan focuses on the objective of "project and sustain the force." It supports the Army Modernization Vision of Land Force Dominance, which flows from the National Military Strategy. In addition, it supports the other four modernization objectives by providing the means to bring them together to achieve Land Force Dominance. This plan assesses systems in the categories of project, sustain, and core support (costs of doing business). Logistics modernization addresses supporting the strategic, operational, and tactical levels of war across the operational continuum. The goal is to project and sustain the U.S. soldier with world-class equipment, in sufficient quantity and as needed, consistent with sound business practices and within funding constraints.

4. Roadmap for Army Logistics

Table III-O-2 presents a summary of SU/ACs and Technology Demonstrations in the Army logistics science and technology program that support Logistics Modernization. The roadmap in Figure III-O-1 portrays the projection of programs to include technology demonstrations, ATDs, and SU/ACs which support Logistics Modernization.

a. Project the Force

The project logistics function encompasses strategic, operational, and tactical mobility needed to rapidly deploy CONUS-based forces and sustain operations to ensure land force dominance and decisive victory. There are five key components of "Project the Force": militarily useful railcars, rapid sealift, versatile airlift, improved airdrop delivery, and flexible Logistics-Over-the-Shore (LOTS). The Army Strategic Mobility Program supports the U.S. Air Force C-17 and U.S. Navy Fast Sealift programs to provide airlift and sealift components. The following demonstration will support the advanced development of the Army's airdrop delivery component.

Table III-O-1. Logistics Modernization Systems Capabilities

SU/AC FUNCTION	BATTLEFIELD DYNAMICS: Early Entry	Depth and Simultaneous Attack	Mounted Battlespace	Dismounted Battlespace	Battle Command	Combat Service Support	SYSTEM UPGRADE CAPABILITIES	ADVANCED CONCEPT CAPABILITIES
PROJECT								
System Upgrades								
Aerial Delivery	●	○		●		●	• Improved precision guided delivery of munitions	
Advanced Concepts								
Precision Offset, High Glide Aerial Delivery	●	●		●		●		• Accurate delivery of supplies/equipment from offset distances • Increased delivery accuracy via an autonomous GPS-based guidance and navigation system • Covert day/night and limited visibility airdrop capability
SUSTAIN								
System Upgrades								
Army Field Feeding Future	○		○	○		●	• Shelf stable ration components • Enhanced rations performance and flexibility • Reduce rations weight and volume • Less soldier labor/fatigue • Reduced manpower • Automated logistics planning • Automated assessment of petroleum products • Improved corrosion protection • Improved munitions protection	
Logistics Survivability	●	●	●			●		
Electric Power Generation	●	○	○	○		●		
Advanced Concept								
Total Distribution System	●	○	○	○	○	●		• Automated logistics planning and execution • Integrated automated logistics database and STAMIS • Total asset visibility with in-transit visibility • Assured logistics capability • Improved port and air head survivability • Enhanced sea bused support • Improved hazardous operations • Multi-dimensional situations • Mission-oriented ship outload • Selective "instream" resupply • Quick access to hazardous areas
CORE SUPPORT								
System Upgrades								
Rapid Deployment Food Service for Force Projection	●		○	○		●	• Improved quality of life (food, water) • Improved air transportability	

● Provides Significant Capability ○ Provides Some Capability

Precision Offset, High Glide Aerial Delivery (94-99). Semi-rigid Deployable Wing (SDW) technology will be used to demonstrate precision, high offset delivery of supplies and equipment. Details can be found in Section H, *Close Combat Light.* **Supports:** Aerial Delivery, Precision Offset, High Glide Aerial Delivery, EELS, DSA, and CSS Battle Labs.

b. Sustain the Force

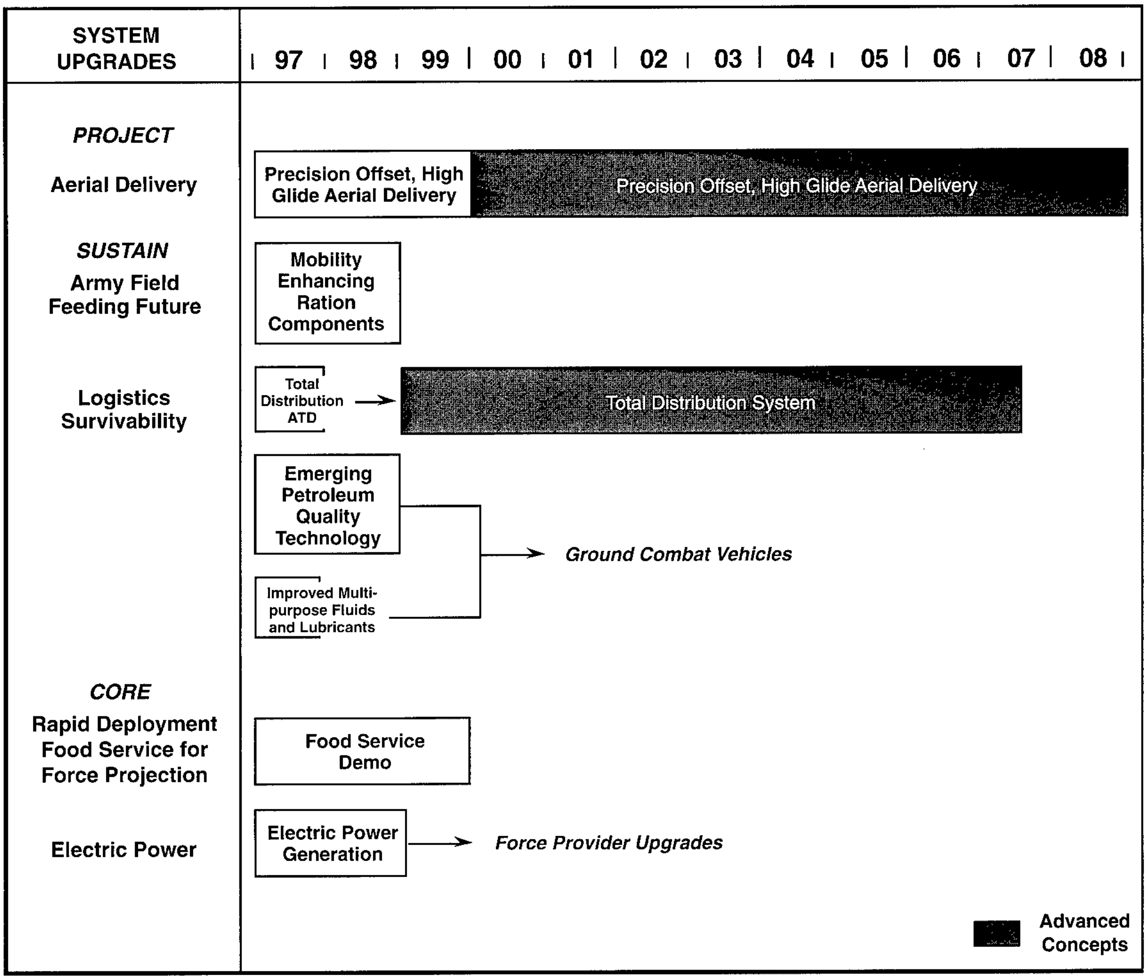
The sustain logistics function includes all services needed to provide ammunition, water, food, fuel, personnel hygiene, mortuary affairs, and personnel support. Medical sustainment of the force is significant. Section J of this chapter discusses the Combat Health Support Moderization Strategy. Modernization of sustainment functions focuses on logistics automation, survivability, and improving the quality of life of soldiers. The following ATD and Technology Demonstrations support sustaining the force.

Total Distribution ATD (TD ATD) (94-97). The TDATD will demonstrate the integration

Table III-O-2. Logistics Demonstrations and Systems Summary

ATDs	TECHNOLOGY DEMONSTRATIONS
• Total Distribution **ACTD** • Joint Logistics (For additional information, see Volume II, Annex B.)	**Sustain Demonstrations** • Mobility Enhancing Ration Components (MERC) • Precision Offset, High Glide Aerial Delivery • Emerging Petroleum Quality Technology • Improved Multipurpose Fluids and Lubricants **Core Demonstrations** • Rapid Deployment Food Service for Force Projection • Electric Power Generation
SYSTEM UPGRADES/ADVANCED CONCEPTS	
System Upgrades • Aerial Delivery • Logistics Survivability • Army Field Feeding Future • Rapid Deployment Food Service for Force Projection • Electric Power Generation	***Advanced Concept*** • Total Distribution System • Precision Offset, High Glide Aerial Delivery

Figure III-O-1. Roadmap for Logistics Modernization



of automated logistics planning tools, computer simulation and modeling techniques, advanced microelectronics, satellite tracking, and communications technology to significantly enhance total asset visibility by displaying the requirements for and the location of assets at the strategic, operational, and tactical levels. The objective Total Distribution System (TDS) would support an enhancement to the Total Distribution Program capability to provide strategic, operational, and tactical commanders with automated logistics planning and visualization capabilities for force deployment, sustainment, and operational execution using artificial intelligence technology and management information system (MIS) data bases. Potential Objective Supply Capability (OSC) upgrades, combined with space and terrestrial communications technology, will be linked to distributed, object-oriented Standard Army MIS (STAMIS) systems and logistics data bases (i.e., transportation, ammunition, supply, and maintenance) to significantly reduce supply planning time and demonstrate a capability to analyze alternative courses of action prior to directing, rerouting, or redistributing assets. **Supports:** Joint Logistics Proposed ACTD, Logistics Survivability, and Total Distribution System.

Improved Multipurpose Fluids and Lubricants Technology Demonstration (94-97). Advanced formulation technologies and new materials will be employed to provide fluid/lubricant products which exhibit improved performance, multifunctionality, and global operability. These products will provide the Army enhanced capabilities in the prepositioning of materiel and supplies, to support mobilization and deployment of forces, and for sustainment of forces once deployed and during offensive operations. The improved fluids and lubricants being demonstrated will use advanced additive technologies and new base materials to meet existing/future equipment needs and comply with environmental initiatives. These products will provide up to 300 percent increase in corrosion protection and will expand operational range of products by 25°F to 90°F. The improved fluids/lubricants will reduce component failures such as battery/starter usage by 25 percent and will reduce waste oil generation on the order of 20 percent. In addition, the products will significantly enhance logistics, replacing multiple existing fluids (3 specifications for 1 specification) and lubricants (2/5 specifications/grades for 1/3 specifications/grades). **Supports:** Logistics Survivability, all ground combat vehicles.

Emerging Petroleum Quality Technology Demonstration (94-98). Advanced technology and automated devices/systems will be employed to provide rapid on-the-spot assessment of bulk and packaged petroleum products from CONUS and/or host nation support. The advanced technologies being demonstrated for Petroleum Quality Analysis (PQA) will use automated analytical techniques and emerging methodologies in conjunction with computer-based expert systems. The devices/systems will replace all existing petroleum laboratories, reduce testing time from 3 hours to 10 minutes, and decrease manpower requirements by 75 percent. This emerging technology is state-of-the-art and will serve as a foundation for follow-on industry efforts. PQA will provide commanders the combat service support equipment required to enhance sustaining momentum, maintaining operational/tactical maneuver freedom, and optimizing the use of locally available supplies. The capability to utilize locally available petroleum products with attendant risks will significantly reduce logistics and enhance mobility of forward units. **Supports:** Logistics Survivability, all ground combat vehicles.

Mobility Enhancing Ration Components (MERCs) Technology Demonstration (96-98). By FY98 the Mobility Enhancing Ration Components (MERCs) will demonstrate technologies of shelf stable, highly acceptable, eat-on-the-move/eat-out-of-hand components for operational rations. Ration components will be suitable for individual or group ration systems that support highly mobile and deployed troops. MERCs will be suitable for arctic, jungle, desert, mountain, and urban environments. The goal is to provide novel ration components (e.g., shelf stable sandwiches) which can be consumed on-the-go with no preparation or heating required and which are compatible with existing ration systems. **Supports:** Army Field Feeding Future.

c. Core Support to the Force

The core support logistics functions are those basic capabilities necessary to keep the Army operating efficiently. These capabilities include providing hot food, electric power generation, modernizing support equipment, explosive safety improvements, and updating aging materiel handling equipment. The following technology demonstrations will support the advanced development of advanced shelters and improved combat living capabilities.

Rapid Deployment Food Service for Force Projection Technology Demonstration (94-99). With renewed emphasis on fresh foods and changes in Army policy from two hot meals per week to one a day, fundamental changes are required in field kitchens to support Rapid Force Projection. This program will demonstrate advances in diesel combustion, heat transfer, power generation, and food storage. The fundamental changes in kitchen design will include centrally heated equipment, integral power, and heat-driven refrigeration. These technologies will be developed, integrated with other improvements on a kitchen platform and demonstrated in field scenarios. The demonstrations will show necessary increases in mobility, deployability, reliability, maintainability, and efficiency that will yield higher quality meals faster and cheaper. **Supports:** Rapid Deployment Food Service for Force Projection.

Electric Power Generation Technology Demonstration (95-98). This TD will support the Army's vision of the digitized battlefield by developing light, highly mobile power sources that support implementation of the "one fuel forward" policy. Commercially available compression ignition engines with piezoelectric injection combustion schemes are being modified. Advanced permanent magnet materials offer lightweight and high temperature tolerant sources of raw AC power (with widely varying AC frequencies). High frequency electronic power switches provide very low weight and high efficiency for the conversion of widely varying AC power to stable AC or DC power. Applicable alternate thermal technologies include thermophoto-voltaics, thermoelectrics, Alkali Metal Thermal Electric Converters (AMTEC), and fuel cells. **Supports:** Electric Power Generation and Force Provider Upgrades.

5. Relationship to Modernization Plan Annexes

Figure III-O-2 shows the correlation between the Logistics System Upgrades/Advanced Concepts and other Army Modernization Plan Annexes.

Figure III-O-2. Correlation Between Logistics SU/ACs and Other Applicable Army Modernization Plan Annexes

LOGISTICS SYSTEM UPGRADES AND ADVANCED CONCEPTS		MODERNIZATION PLAN ANNEXES: Close Combat Light	Soldier Systems	Aviation	C4	Combat Health Support	Fire Support	Mounted Forces	Air Defense Artillery	Tactical Wheeled Vehicles	Theater Missile Defense	Training	Engineer & Mine Wa	Logistics
System Upgrades	Aerial Delivery	●	○	●										●
	Army Field Feeding Future	○	●			○								●
	Rapid Deploy. Food Service for Force Proj.	○	●											●
	Logistics Survivability	○	○	●			●	●	●	○	○			
	Electric Power Generation				○				○		○			●
Advanced Concepts	Precision Offset, High Glide Aerial Delivery	○	○	●										●
	Total Distribution System	○	○	○	●									○

● System plays a significant role in the Modernization Strategy.

○ System makes a contribution to the Modernization Strategy.

P.

Training

We must find the best ways to organize, train, and equip our forces to exploit our competitive advantages—quality people and advanced technology.

General Reimer,
Chief of Staff, U.S. Army

1. Introduction

The new national security strategy stresses preparation to defend against nuclear threats, threats from regional powers, threats to evolving democratization, and regional instabilities. A force projection Army must be ready to carry out changing roles and missions at any time, anywhere in the world.

Army training can meet this challenge through the application of behavioral science and emerging technologies to individual, collective, and leader training. These advances will be used to increase mission readiness for both the active and reserve forces and improve the training for new missions and new environments, such as Stability Operations. Commanders will be able to provide tough, realistic, battle-focused training to provide soldiers and leaders the ability to fight and win within a constrained training budget.

2. Relationship to Operational Capabilities

The Combined Arms Training Strategy (CATS) is the Army's architecture for training and educating its people and units. CATS provides the conceptual framework for establishing training policy and resource requirements. The objective of the CATS architecture is to provide doctrine-based strategies for training warfighting tasks and skills in institutions, units, and through self-development.

Under Project Reliance, the Army manpower, personnel, and training R&D community has the Department of Defense lead for development and demonstration of technology for:

- Unit collective training
- Rotary-wing pilot training
- Land warfare training
- Human resources
- Leader development

Table III-P-1 presents the correlation between TRADOC's Battlefield Dynamics and training system upgrades and advanced concepts (SU/ACs). It also shows proposed training system capabilities by Battlefield Dynamics. Simulation-based training and training strategies cut across all Battlefield Dynamics, although special emphasis is given to combined arms operations for both large and small units.

3. Army Modernization Strategy

America's 21st Century Army will train on a digitized battlefield consisting of a close integration of live, virtual, and constructive simulations. Training strategies, organizational redesign, leadership development, and personnel issues will evolve into an interactive cycle of experimentation and assessment with actual units and in support of the Battle Labs.

As stated in the FY96 Army Modernization Plan:

> *"The challenge is to train and sustain the most combat ready and deployable force in the world. The Army must look to research and development initiatives to identify technology that may offset decreasing force structure and ensure the means of providing realistic, dynamic training to our soldiers—today and tomorrow."*

Current and developmental system concepts are focused through the following training programs:

- Distributed Interactive Systems (DIS)
- Combined Arms Tactical Trainer (CATT).
- Family of Simulations (FAMSIM) including Warfighters' Simulation (WARSIM) 2000, Tactical Simulations (TACSIM), Command and Control Simulations.
- Combat Training Centers (CTC): National Training Center (NTC), Joint Readiness Training Center (JRTC), Combat Maneuver Training Center (CMTC), and Battle Command Training Program (BCTP).
- Non-System Training Devices (NSTD).
- Range Instrumentation, Targetry, and Devices.

Table III-P-1. Training System Capabilities

SU/AC FUNCTION	BATTLEFIELD DYNAMICS: Early Entry	Depth and Simultaneous Attack	Mounted Battlespace	Dismounted Battlespace	Battle Command	Combat Service Support	SYSTEM UPGRADE CAPABILITIES	ADVANCED CONCEPT CAPABILITIES
VIRTUAL SIMULATION								
System Upgrades								
Combined Arms Tactical Trainer	○	●	●	●	●	●	• Combined arms training	
Family of Simulations	●	●	●	●	●	●	• Battle command training	
Distributed Interactive Simulation	●	●	●	●	●	●	• Synthetic battlefield	
Combined Arms Training Strategy	○	●	●	●	●	●	• Combined arms training	
Advanced Concepts								
Innovative Simulation-Based Training Strategies	●	●	●	●	●	●		• Joint mission training • Mission rehearsal
Assessment and Leader Development Technologies	●	●	●	●	●	●		• Mission readiness estimation • Behaviorally accurate SAFOR
CONSTRUCTIVE SIMULATION								
Advanced Concepts								
Distributed Models/Simulations for Joint/Theater Exercises	●	●	●	●	●	●		• Joint mission training • Mission rehearsal • Mission readiness estimation
LIVE SIMULATION								
System Upgrades								
Combat Training Centers (CTC) NTC JRTC CMTC BCTP	●	●	●	●	●	●	• Performance data collection/ analysis (UPAS) • Contingency mission training • Special operations training • Joint services training • Range modernization	
Non-System Training Devices (NSTD)	●	●	●	●	●	●	• Upgrades of MILES equipment	
Range Instrumentation/Targetry/ Devices			●	●	●		• Range modernization	

VIRTUAL SIMULATION: Systems and troops in simulators fighting on synthetic battlefields.
CONSTRUCTIVE SIMULATION: Wargames, models, analytical tools.
LIVE SIMULATION: Operations with real equipment in the field.

● Provides Significant Capability ○ Provides Some Capability

Taken together, upgrades to these programs provide training aids, devices, simulators, and simulations (TADSS) that will provide the means for meeting the Army's training modernization objectives.

Future training technology initiatives must have high potential payoff (i.e., reduced training time and resource consumption). Initiatives must offer solutions which offset a decreasing force structure and ensure the means for providing realistic, dynamic training at both home station and the Combat Training Centers (CTCs). CTCs must be upgraded and augmented by training aids and devices to provide a cost-effective training environment, using warfighting equipment in conjunction with simulated environments. A Distributed Interactive Simulation (DIS) capability combined with Virtual Reality (VR) technology will permit the development of synthetic battlefields for training that complement field training exercises at the CTCs.

4. Roadmap for Army Training

Table III-P-2 summarizes the training SU/ACs and relevant technology demonstrations. The roadmap at Figure III-P-1 details the Army's current plans to support future training initiatives. Limited advanced development funding for Training System Upgrades is available in the outyears.

CTCs represent realistic training environments using actual equipment on large, instrumented maneuver areas or advanced simulation programs. Standardized instrumentation systems at all CTCs provide precise measurement of unit performance in these simulated combat environments. NSTD upgrades include improved Multiple Integrated Laser Engagement System (MILES) Air/Ground Engagement Simulation (AGES II) for more effective integration of aviation operations into CTC exercises.

The Combined Arms Training Strategy is the framework that leaders will use to design and execute effective unit training programs in a resource-constrained environment. Supporting technology demonstrations that will lead to the Advanced Concepts, shown in Figure III-P-1, are described below.

a. Technology Programs for Collective Training

Combat training readiness for a wide spectrum of conflicts is a top priority for the Army. CATS seeks to provide the guidance home station training leaders need to achieve training excellence with constrained budgets and time.

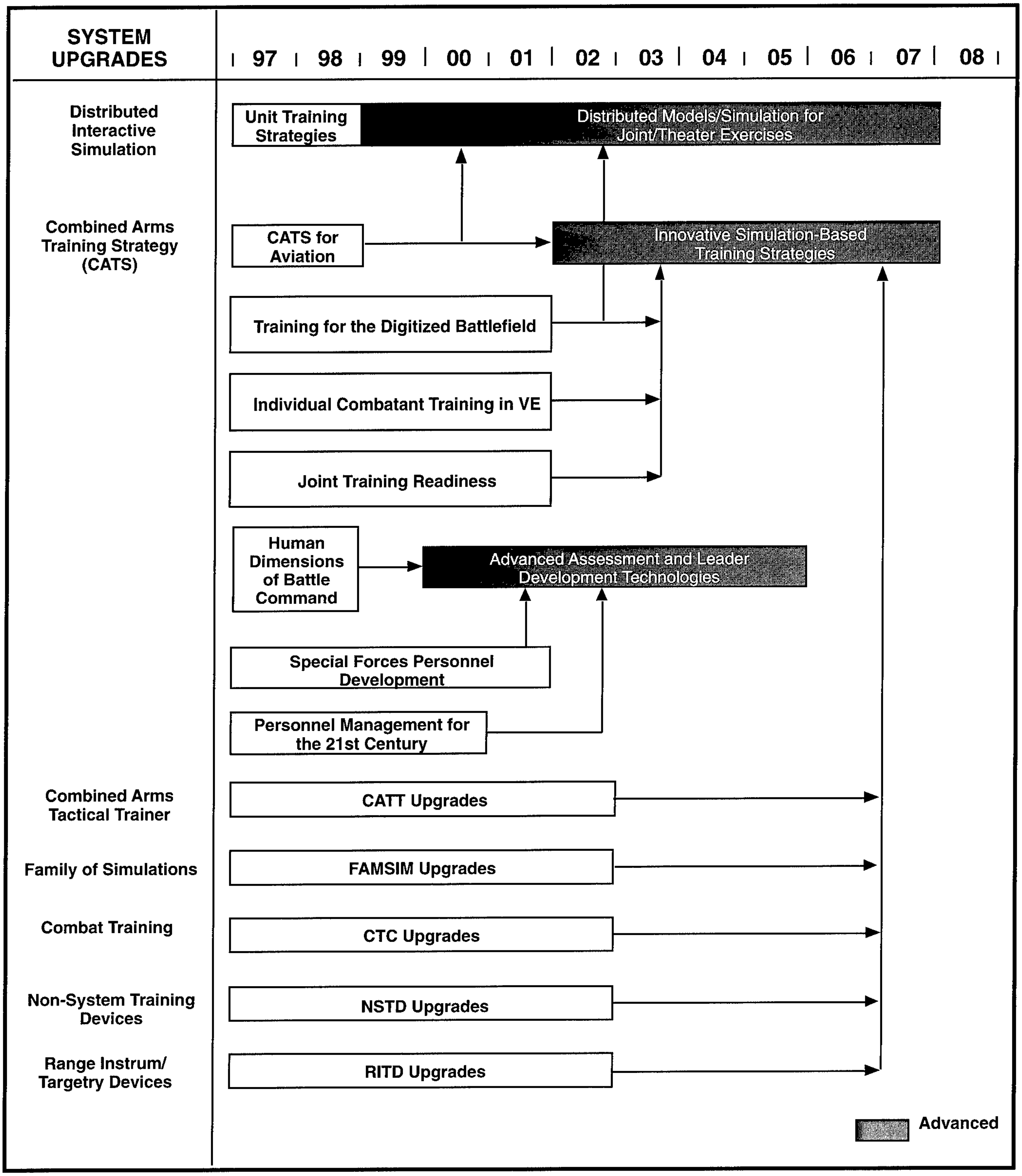
Table III-P-2. Training Demonstration and System Summary

ATDs (ARPA ATDs)	TECHNOLOGY DEMONSTRATIONS
• Synthetic Theater of War (STOW) • Simulation in Training for Advanced Readiness (SIMITAR)	**Collective Training** • Unit Training Strategies • Training for the Digitized Battlefield **Simulator/Simulation Training** • Joint Training Readiness • Combined Arms Training Strategy for Aviation • Individual Combatant Training for VE **Improved Personnel Performance** • Human Dimensions of Battle Command • Special Forces Personnel Development • Personnel Management for the 21st Century

TRAINING SYSTEM UPGRADES AND ADVANCED CONCEPTS

System Upgrades	*Advanced Concepts*
• Distributed Interactive Simulation • Combined Arms Training Strategy • Combined Arms Tactical Trainer • Family of Simulations • Combat Training Centers • Non-system Training Devices • Range Instrumentation, Targetry, and Devices	• Distributed Models/Simulation for Joint/Theater Exercises • Innovative Simulation-Based Training Strategies • Advanced Assessment and Leader Development Technologies

Figure III-P-1. Roadmap for Training Modernization



The following programs support the CATS through intelligent and affordable unit training strategies and by improving commander and staff effectiveness through research on training, doctrine, leadership, and organizational design.

Unit Training Strategies (92-98). This research program will provide an empirical basis for developing effective unit training strategies for armored and light forces, aircrews, and reserve components. This will be accomplished by developing new training methods and determining an optimal mix of existing TADSS and live firing and field exercises. Much of this work is aimed at discovering better ways to train with distributed interactive simulation. For example, in FY97, one program will develop methods for structuring armor training and automating performance measurement, feedback, and training management in the close combat tactical trainer (CCTT) programs. Results will also be used to update battalion level training models in FY98. **Supports:** Distributed Interactive Simulation and Distributed Models/Simulation for Joint/Theater Exercises.

Training for the Digitized Battlefield (96-01). The research program will develop and demonstrate new training and evaluation technologies that will prepare operators and commanders to take maximum advantage of evolving digitized C3 systems. Techniques and strategies will be demonstrated and evaluated in Advanced Warfighting Experiments (AWEs). New training and evaluation technologies for the digitized battlefield will be used by TRADOC as the foundation of future doctrine and cost-effective training strategies. **Supports:** Combined Arms Training Strategy (CATS), Innovative Simulation-Based Training Strategies, and Distributed Models/Simulation for Joint/Theater Exercises.

b. Technology Programs for Simulator/ Simulation Enhanced Training

Today's Army must be capable of producing swift, decisive, low-casualty victories across the spectrum of conflict anywhere in the world. Simulated environments can be tailored to provide realistic training for new critical missions. For example, prototype simulation-based training methods are being developed to train light forces for Stability Operations. Other programs are developing innovative simulation-based training approaches for joint exercises, dismounted soldiers, and aviators. These programs include:

Joint Training Readiness (97-01). This research supports the Joint Warfighter Focus Army Modernization Objective. By FY99 the program will provide methods for planning and conducting systematic multi-site, multi-echelon After Action Reviews of interservice and joint unit operations. In FY00, the program will demonstrate distributed training methods for planning and executing tactical fires from Brigade through Corps as a Joint Task Force. **Supports:** Innovative Simulation-Based Training Strategies and CATS.

Individual Combatant Training in Virtual Environments (97-01). This research program will develop technologies to allow dismounted soldiers to participate in virtual simulations for training, concept development, and test and evaluation similar to their mounted counterparts. Methods for training team leaders and assessing performance will be demonstrated using state-of-the-art Virtual Environment (VE) technology. **Supports:** Innovative Simulation-Based Training Strategies and CATS.

Combined Arms Training Strategy for Aviation (92-98). This research has as its purpose the empirical determination of the most effective training strategies utilizing an affordable mix of existing TADSS and live exercises for initial flight skills for individuals and for unit combat tasks. This research will establish requirements for utilization of and upgrades to existing simulators. In FY98, the research will deliver an experimentally validated prototype aviation training strategy for individual pilot and unit combat tasks. **Supports:** Distributed Interactive Simulation and Distributed Models/Simulation for Joint/Theater Exercises, Innovative Simulation-Based Training Strategies, and CATS.

c. Technology Programs for Improved Personnel Performance

Today's smaller Army must act wisely to ensure that its strength, quality, and readiness can meet the demands of a wider range of operations. Key to this challenge is enlisting and retaining quality soldiers and understanding how to manage organizational changes. Properly placed, quality soldiers save recruiting, training, and supporting dollars. The following programs describe research addressing these issues.

Human Dimensions of Battle Command (93-98). This research will determine the key factors in the effectiveness of tactical and operational unit commanders and their staffs, with an emphasis on the impact of doctrine, training, technology, and organizational influences. Research products will support changes in staff training, command staff design, and command staff training strategies. A major goal is to demonstrate a significant improvement in the tactical decision skills of commanders in the Battle Command Battle Lab advanced warfighting experiments (AWE). **Supports:** Advanced Assessment and Leader Development Technologies and CATS.

Special Forces Personnel Development (95-01). This research will develop methods, models, and strategies to meet the particular needs of the Special Forces to improve training (e.g., leveraging and developing advanced technologies for foreign language training), reduce training attrition, and enhance leader and personnel development. **Supports:** Advanced Assessment and Leader Development Technologies and CATS.

Personnel Management for the 21st Century (97-00). The objective of this research is to identify noncommissioned officers who can operate most effectively in the complex, high-tech Army of the future. The work involves identifying performance requirements and the attributes that underlie successful performance. By FY00, the program will produce new methods for assessing NCOs and recommendations for fine-tuning career progression procedures. **Supports:** Advanced Assessment and Leader Development Technologies and CATS.

d. Other Training Modernization Programs

The Army's manpower, personnel, and training science and technology program supports these activities as well as the majority of the Battle Labs' advanced warfighting experiments.

ARPA Advanced Technology Demonstration #1 (Synthetic Theater of War (STOW)). STOW uses Advanced Distributed Simulation (ADS) to link live, virtual, and constructive simulation systems into a synthetic environment battlefield. The program grew out of the Synthetic Environment Program (SEP) initiated in 1994. A demonstration is planned for FY97.

ARPA Advanced Technology Demonstration #2 [Simulation in Training for Advanced Readiness (SIMITAR)]. SIMITAR was initiated to address training readiness issues identified during mobilization for Operation Desert Shield. Results led to congressional interest and funding (FY93-97) for DARPA-led research on advanced technology training for the Army National Guard (ARNG). The effectiveness of SIMITAR training technologies will be validated in two ARNG brigades in FY97-98.

5. Relationship to Modernization Plan Annexes

Figure III-P-2 shows the correlation between Army training SU/ACs and other Army Modernization Plan Annexes.

Figure III-P-2. Correlation Between Training S/SU/ACs and Other Modernization Plan Annexes

TRAINING SYSTEM UPGRADES/ ADVANCE CONCEPTS		MODERNIZATION PLAN ANNEXES: Mounted Forces	Close Combat-Light	C4	Engineer & Mine Warfare	Air Defense Artillery	Tactical Wheeled Vehicles	Fire Support	Theater Missile Defense	Intelligence & Electronic Warfare	Logistics	Soldier Systems	Aviation	Nuclear, Biological & Chemical	Information Mission Area	Combat Health Support	Space
System Upgrades	Distributed Interactive Simulation			●				●		●	●						
	Combined Arms Training Strategy	●	●	○	●	●		●		○	○		●		○		
	Combat Training Centers (CTC)	○	○	○	○	○	○	●	●	●			●		○		○
	Non-System Training Devices (NSTD)	●	●		●	●	○	●		○		○	●	●	○	●	
	Range Instrumentation/Targetry and Devices	●	●				●					○			○		
	Combined Arms Tactical Trainer	●	●	○	●	●		●		○	○		●		○		
	Family of Simulations			●						●	●				○		
Advanced Concepts	Dist Models/Sim for Joint/Theater Exercises	●	●	●	●	●	○	●		○	○	○	●		○		
	Innovative Simulation-Based Tng Strategies	●	●	●	○	○	○	●		○		○	●		○		
	Adv. Assessment and Leader Develop. Tech.	○	○	○		○		○		○		●	○				

● System plays a significant role in the Modernization Strategy.

○ System makes a contribution to the Modernization Strategy.

Q. Space

1. Introduction

The future success of Army forces and their mission will be critically dependent upon the successful exploitation of space assets, capabilities, applications, and products. Space technologies will aid the Army in the areas of information operations, space control, intelligence collection and exploitation, target acquisition, navigation, long and short distance communications (by maintaining line of sight despite intervening obstacles), warning of ballistic missile attacks and other pending threats to land forces and individual soldiers, location and management of logistics assets including automated exchange of logistical data, environmental monitoring, mapping and charting of the earth's surface, and weapons guidance over occupied and unoccupied terrain. Changes in force structure, transition from a forward deployed to a force (power) projection Army, and changes in Army missions have increased the importance of space in standard and special operations.

The ability to improve space-based capabilities hinges on the application of advanced technology. Some of these technologies will improve sensitivity and increase the capacity of existing systems while others are designed to extend the life of space systems and provide more versatility in applications. The Army role is not in building, launching, or operating space systems independently, but in developing, procuring, and fielding ground terminals, integrating space with non-space systems, user equipment, and ensuring that mission payloads address a wider range of Army requirements.

The Army is developing technologies to better support the warfighter using space-based assets and space applications. The Army's goal is to make the use of space a standard part of the planning for all appropriate Army operations and an integral part of the execution of all missions. This normalization of space provides the best utilization of technological capabilities to support warfighters, and the Army space policy to:

- Capitalize on existing and emerging space-related systems' capabilities.
- Exploit space activities that contribute to the successful execution of Army missions as part of a total force.
- Support assured access to space and use of space-related capabilities to aid strategic, operational, tactical, and special operations missions.

2. Relationship to Operational Capabilities

Space systems and space applications are continuing to increase in importance to operational capabilities. The use of satellite communications, terrain and navigation using Global Positioning Systems (GPS), satellite weather forecasting, space systems to conduct information operations, intelligence collection, and threat warning systems to support operations are indications of the success the Army has had in normalizing space into standard operating procedures. The use of space products supports Army doctrine during peacetime and in times of conflict.

As space applications are primarily in the area of force enhancement and force application, the Army looks at the exploitation of space systems as a valuable means of enhancing existing systems and inserting operational capabilities not previously available. In addition, many space applications can be implemented by the use of commercial systems. One example of this is the commercial space package procured by the Army in FY94/95, which consists of commercial fixed and mobile satellite terminals, commercial weather receivers, mission planning and rehearsal systems, the prototype Tri-band satellite communications terminal, and the multispectral image processing systems. This equipment is available from Army Space Command to support contingencies and deployment exercises by providing initial communications, mapmaking capability, in-theater weather forecasting, and mission planning and rehearsal. Table III-Q-1 represents the relationship between the Space Modernization areas and Systems, Systems Upgrades and Advanced Concepts (S/SU/ACs). Force application will, in the near term, involve the protection of North America from ballistic attack and will include Army systems to counter such attacks.

Table III-Q-1. Space System Capabilities

S/SU/AC FUNCTION	BATTLEFIELD DYNAMICS: Early Entry, Lethality, and Survivability	Depth and Simultaneous Attack	Mounted Battlespace	Dismounted Battlespace	Battle Command	Combat Service Support	SYSTEM/SYSTEM UPGRADE CAPABILITIES	ADVANCED CONCEPT CAPABILITIES
COMMUNICATIONS ***System Upgrades*** SCAMP Terminals Communications ***Advanced Concepts*** Communications Transport Adv. Image Collection & Processing Force XXI	○	○	○	○	●	○	• Digital battlefield communications terminal upgrades • SATCOM paging • Forward area comm beyond line of sight	• SATCOM on-the-move • High capacity voice, data, and video transmission
POSITION/NAVIGATION	○	●	○	○	○	○	• Improved weapons pointing	• 1 mil pointing accuracy using GPS
INTELLIGENCE SUPPORT *(Collection and Processing)* ***System Upgrades*** TENCAP Multiple Launch Rocket System	●	○	○	○	●	○	• Improved situation awareness • Improved targeting • Improved pointing accuracy	• Target geolocation <80 meters • Tactical direct downlinks • Tactical direct sensor tasking
THEATER INTELLIGENCE SUPPORT	●	○	○	○	●	○	• Satellite direct access	• Theater direct access terminals
TMD ***System*** JTAGS ***System Upgrade*** TMD Weapons	○	●	○	○	●	○	• Real-time warning to theater forces • Target location • Laser boresight • Pager warning to troops	
SPACE CONTROL	●	●	●	●	●	○	• Anti-satellite system capabilities	• EW, DEW, KEW systems

● Provides Significant Capability ○ Provides Some Capability

3. Space Modernization Strategy

This year, Space Modernization includes "Space Exploitation." There are space applications that support all of the Army modernization objectives. Communications supports Project and Sustain, Joint Tactical Ground Terminals are used to provide missile and other warning to protect the force, numerous command and control efforts are used in winning the information war, space-based intelligence and Tactical Exploitation of National Capabilities (TENCAP) systems support battlefield visualization planning, precision strike, and targeting and the use and applications of GPS and GPS enhancements assist in dominating maneuver.

As our potential adversaries continue to acquire modern technology to update their systems, it is clear that Army access to and exploitation of space capabilities must be upgraded through a continuous modernization program, inserting high leverage technologies to bring about superior capabilities from space to the Army warfighter. These long-term needs will be met by efforts that are planned and programmed today.

In the near term, part of the space modernization strategy is to leverage, buy, and exploit commercial civil and military systems, terminals, and receivers for application on current satellite systems. This strategy includes defining requirements and focusing technologies to provide for future applications of planned systems, as well as influencing the design and development of future satellite systems to satisfy Army requirements. For example, in the case of leveraging assets from civil agencies, the Army is working with NASA and the Air Force to use the NASA Lewis and Clark Spacecrafts to satisfy some Army imagery requirements. Additionally, the Army has participated in the development of the systems requirements for two Air Force programs, the Space-Based Infrared Systems program and the small spacecraft, Warfighter-1. The Army's active involvement with these programs in the early phases of development helps to ensure that Army warfighting requirements are addressed in the design of these systems.

The growing importance of space support to the theater warfighter will require changes from current centralized processing to theater direct downlink and direct access terminals. The approval of the Tactical Satellite System by the Joint Requirements Oversight Council validated the requirement for support of these operations. Limited or dedicated payload tasking and control by in-theater forces will provide the capability to satisfy the space support requirements.

Table III-Q-2 lists the ATDs, Technology Demonstrations and S/SU/ACs for Space Exploitation.

4. Roadmap for Space Systems

Army efforts in the application of space are to normalize space applications in operations in the Army. Toward this objective, a number of projects are ongoing for the application and development of technologies to exploit space to meet Army requirements. The roadmap for Space Exploitation is shown in Figure III-Q-1. The projects in the Space Exploitation area follow.

Digital Battlefield Communications (DBC) ATD (95-99). The DBC ATD demonstrates a secure, robust, seamless, digital, multimedia information transport capability for the Army tactical user. It is discussed in detail in *C4*, Section E.

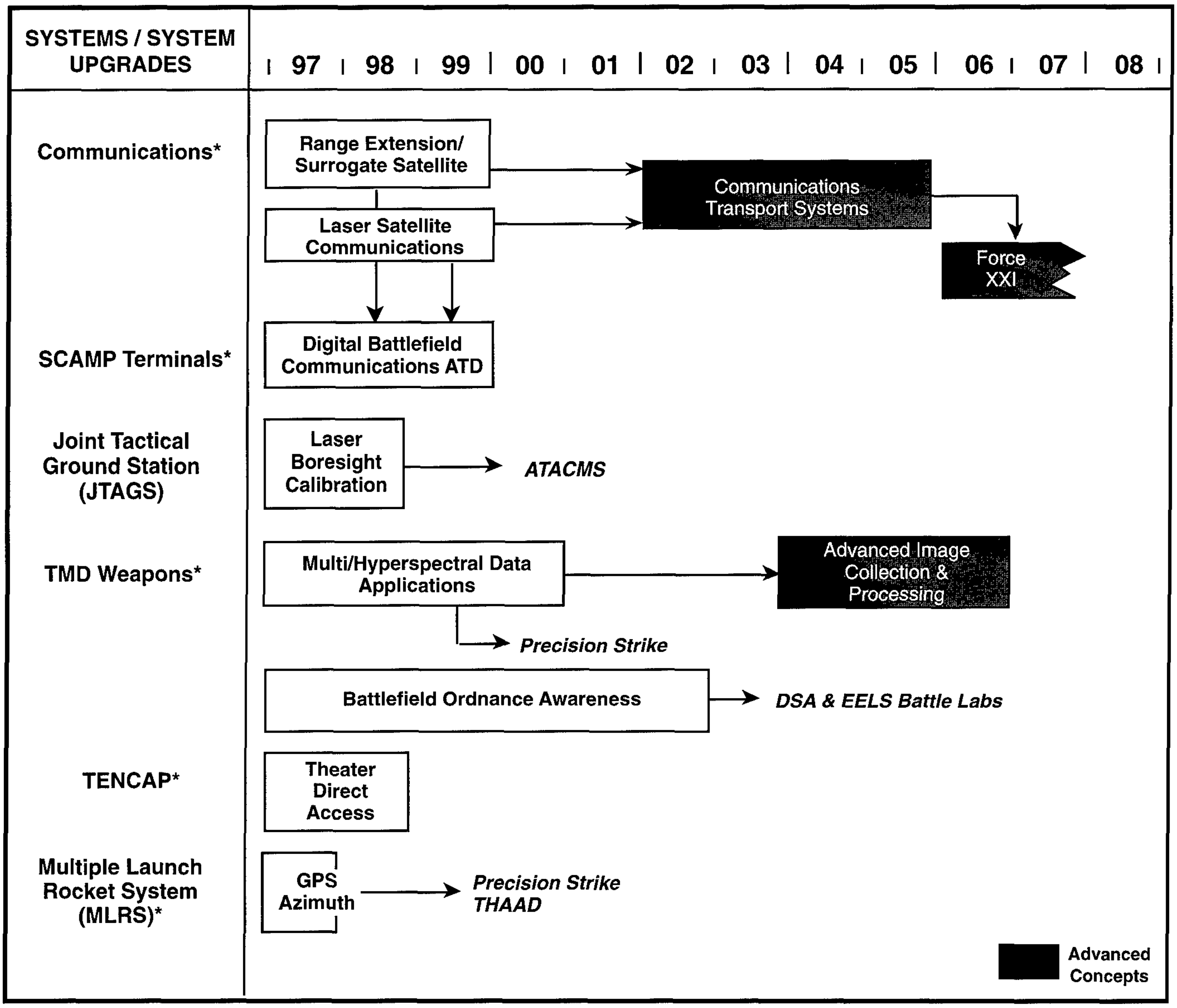
GPS Azimuth Determining System (90-97). The GPS Azimuth Determining System (GPS ADS) is a combat multiplier that provides pointing with survey quality accuracy using the principle of microwave interferometry to signals transmitted from NAVSTAR GPS to provide azimuth, position, elevation, and roll to

Table III-Q-2. Space Demonstrations and Systems Summary

ATDs	TECHNOLOGY DEMONSTRATIONS
• Digital Battlefield Communications (see *C4)* (See Volume II, Annex B, for additional information.)	• GPS Azimuth Determining System • Theater Direct Access • Multi/Hyperspectral Data Applications • Laser Satellite Communications • Battlefield Ordnance Awareness • Laser Boresight Calibration • Range Extension/Surrogate Satellite

SYSTEMS/SYSTEM UPGRADES/ADVANCED CONCEPTS	
System • Joint Tactical Ground Station (JTAGS) ***System Upgrades*** • Single-Channel Anti-Jam Manportable (SCAMP) Terminals • Communications • Tactical Exploitation of National Capabilities (TENCAP) • Theater Missile Defense (TMD) Weapons • Multiple Launch Rocket System (MLRS)	***Advanced Concepts*** • Communications Transport • Advanced Image Collection and Processing • Force XXI

Figure III-Q-1. Roadmap for Space



*System Upgrades

an azimuth accuracy of 1.0 mils and elevation accuracy to 3.5 mils in 4 seconds. The GPS ADS will be used to meet the pointing requirements of indirect fire weapons, radars, intelligence systems, communications tracking, combat aviation, maneuver, blue force tracking, and forward observers. It will be installed on numerous platforms as a system enhancement. **Supports:** System upgrades in Multiple MLRS, AFAS, Precision Strike, Trailblazer, and THAAD.

Theater Direct Access Demonstration (95-98). A tactical satellite launched by DARPA will be used to conduct a proof of concept technology demonstration with Army TENCAP systems to show the capability of satellite mission tasking direct from theater forces. The Joint Army/DARPA/NSA program will conduct the technology demonstration of this concept in support of Early Entry and Battle Command doctrine. **Supports:** Tactical Satellite system and system upgrades to Army TENCAP.

Multi/Hyperspectral Data Applications (94-00). The Army will demonstrate several technologies to be used in the collection of multispectral and hyperspectral imagery for the exploitation of remote earth sensing imagery. This has applications in the areas of reconnaissance and intelligence, as well as terrain analysis. The collection sensors will be used to develop the data base required to identify spectral signatures for future exploitation. The prototype sensor will demonstrate Army tactical utility in ground and flight test. Combine phenomenology between spectral and polarization will be investigated for detection and identification of tactical targets. These sensors will assist in the development of Army requirements for the next generation of remote earth sensors. Sensor technology will transition to Army sensor packages, to UAV, or to space systems. **Supports:** Precision Strike, TMD Weapons, and Advanced Image Collection and Processing.

Laser Satellite Communications (95-99). A proof of concept demonstration will be conducted using ground-to-ground and ground-to-air systems for laser communications. This technology has the potential to increase the data capacity above that of existing communications while decreasing the weight, size, and power requirements. Data rates up to 1 gbps are possible. The proof of concept will be developed into a technology demonstration and in the future transition into a dual use terminal or a tri-band to support the Common Ground Station. Mountain top-to-mountain top experiments have been successfully completed. Feasibility studies are being done to assess the ground-to-ground and space-to-ground roles. More hardware is being built to perform ground-to-ground and ground-to-air experiments. Future experiments will put hardware on a satellite to perform space-to-air and space-to-ground experiments. **Supports:** Digital Battlefield Communications ATD, Communications Transport System, and Force XXI.

Battlefield Ordnance Awareness (BOA) (FY96-02). The program is to demonstrate a near real-time ordnance reporting system using onboard processing with space sensors. This technology will improve battlefield visualization of friendly and enemy ordnance fires and cruise missile launches. It addresses the need to target ordnance delivery for counterfire purposes, a major battlefield deficiency. The BOA capability will identify the ordnance by type and provide position information for counter fire opportunities, as well as Battle Damage Assessment, blue forces ordnance inventory, information for dispatch for logistical and medical support, and search/rescue. Advanced processor technology will be used with state-of-the-art plane staring arrays to provide critical information to the commander. **Supports:** TMD Weapons, Depth and Simultaneous Attack, Early Entry Battle Labs, and Field Artillery Systems.

Laser Boresight Calibration (95-98). This program will develop a solid-state laser calibration capability for Joint Tactical Ground Station (JTAGS) system. The laser calibrator will provide a known ground registration point for space-based sensors resulting in improved launch point predictions and impact area for Theater Ballistic Missiles (TBM). It will reduce the command and control timelines plus improve the overall responsiveness of the Joint Precision Strike and TMD forces by significantly reducing the TBM search box. The improved line-of-sight target accuracy will result in higher quality missile warning, alerting, and cueing information. This capability will be integrated into the JTAGS P3I. **Supports:** Theater Missile Defense (TMD)-JTAGS, Army Tactical Missile System (ATACMS).

Range Extension/Surrogate Satellite (94-99). The goal of this demonstration is to support Army C4I modernization by developing and demonstrating key technologies and capabilities for flexible and affordable intra-theater long range communications. It includes the use of surrogate satellites, enhancements to current SATCOM equipment, and unmanned aerial vehicle (UAV) cross links. A range extension testbed was developed in FY96, followed by commercial UAV demonstrations, SATCOM terminal modifications in FY97 (to use with the relay/surrogate satellite), battlefield paging, network controller and switching, and UAV cross links to be completed in FY99. A fully integrated demonstration of a SHF network will be conducted in FY99. This demonstration also supports C4, and is referenced further in *C4*, Section III-E. **Supports:** Digital Battlefield Communications, UAV Payload Program, Communications Transport System, Force XXI.

5. Relationship to Modernization Plan Annexes

Figure III-Q-2 shows the relationship between the Space S/SU/ACs and Army Modernization Plan Annexes.

Figure III-Q-2. Correlation Between Space S/SU/ACs and Other Modernization Plan Annexes

SPACE SYSTEM/SYSTEM UPGRADES/ADVANCED CONCEPTS		MODERNIZATION PLAN ANNEXES: Aviation	IEW	Fire Support	Close Combat Light	C4	Air Defense Artillery	Logistics
System	Joint Tactical Ground Station (JTAGS)		●	○	○	●		
System Upgrades	TMD Weapons		○			○	●	
	Tactical Exploitation of National Capabilities (TENCAP)		●	●	○	○		
	SCAMP Terminals		○	○	○	●	○	○
	Communications		○			●		
	Multiple Launch Rocket System (MLRS)			●	○	○	●	
Advanced Concepts	Communications Transport	○	○	○	○	●	○	○
	Advanced Image Collection and Processing	○	●	○	○	○		
	Force XXI	○	●	○	○	○	○	○

● System plays a significant role in the Modernization Plan.

○ System makes a contribution to the Modernization Strategy.

CHAPTER IV

Technology Development

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CHAPTER IV

TECHNOLOGY DEVELOPMENT

A. Introduction

Chapter IV reflects the Army's investments to implement its post-Cold War science and technology vision and strategy, as described in Chapter I, Strategy and Overview, and in Chapter II, Science & Technology Integration with Army XXI Requirements Determination. This chapter addresses the Army's 6.2 investment strategy, which is presented as 19 areas that are adapted from the subarea architecture of the Defense Technology Area Plan (DTAP). The DTAP taxonomy changed in FY96, consolidating 19 Defense Technology Areas from the prior year into 10, and assigning some of those areas to subarea status. This chapter has retained the 19-area format initially adopted in the FY96 ASTMP. The link between the Defense Technology Areas and the chapter sections is shown in Table IV-A-1.

Table IV-A-1. Defense Technology Areas/Chapter IV Taxonomy

DEFENSE TECHNOLOGY AREA	RELATED CHAPTER IV SECTION
Air Platforms	Portions of Air and Space Vehicles Portions of Aerospace Propulsion and Power
Chemical & Biological Defense and Nuclear	Chemical & Biological Defense and Nuclear
Information Systems and Technology	Command, Control, and Communications Computing and Software Modeling and Simulation
Ground and Sea Vehicles	Ground Vehicles
Materials/Processes	Materials, Processes, and Structures Civil Engineering/Environmental Quality Manufacturing S&T
Medical and Biomedical	Medical and Biomedical S&T
Sensors and Electronics	Sensors Electron Devices Battlespace Environments
Space Platforms	Portions of Air and Space Vehicles Portions of Aerospace Propulsion and Power
Human Systems	Human Systems Interface Individual Survivability and Sustainment Manpower, Personnel, and Training
Weapons	Conventional Weapons Electronic Warfare/Directed Energy Weapons

Linkage of the Technology Objective tables with their related TRADOC Operational Capability Requirements (OCRs) started in the FY96 ASTMP and is continued this year. A listing of current OCRs is provided in Volume II, Annex C, of this plan.

The Army's basic research, applied research, and advanced technology development work emphasizes technology that can be applied to upgrade currently fielded systems. This focus helps maintain an operational edge for the near term while simultaneously developing technologies to ensure future land force dominance in the mid to far term. The thrust of the Army investment is to capitalize on technology opportunities, to reduce technology barriers, and to exploit emerging technology options for essential battlefield capabilities—as defined by our warfighters.

The Army investment in Applied Research enables advanced concepts for land combat, and constitutes the critical technology development link between the Army's basic research thrusts discussed in Chapter V and the Army Modernization Plan Annexes and roadmaps described in Chapter III.

B.

Strategy

Consistent with the commitment to sustain its science and technology base, the Army 6.2 program identifies and focuses on selected technologies that will provide the maximum warfighting capability for every dollar invested. This demands a significant dual commitment to in-house Army applied research and to the expansion of cooperative efforts with the other Services and industry. The Army leverages research and technology opportunities in academia, industry, and the international community to promote efficiency and synergy at all levels. The Army Research Laboratory implementation of the federated laboratory concept in 1996 will play a major role in this strategy. The technology leveraging and transfer program is discussed more fully in Chapter VII.

The Army S&T oversight process, as described in Chapter I, prioritizes technology needs and opportunities based upon their potential to provide critical battlefield capabilities. These capabilities are jointly defined by the combat and materiel developers. The early and continuous involvement of the warfighter in the S&T capabilities definition process allows for a balanced look at the "Technology Push" coming from the Army's S&T community and the "Requirements Pull" prompted by the immediate needs of the warfighter. A mechanism which promotes this alignment is the interplay between the combat and materiel developers that occurs during the Army STO Reviews and the TRADOC S&T Reviews. Both take place in the spring, and result in an S&T program that is more attuned to warfighter needs.

Studies by the BAST-STAR Panel, the Defense and Army Science Boards, the Army's in-house S&T community, and the TRADOC battle labs and schools have all recommended that Army S&T focus on "critical" technologies. The Army 6.2 investment in the 19 technology areas reflects this commitment to eliminate the barriers that impede technology opportunities presented by the most promising state-of-the-art advances. While its main focus is providing capabilities for land force dominance, the Army investment is also aligned with the DoD strategy as summarized in Chapter I.

Each section in this chapter is structured to define the technology area, to summarize the Army's ongoing technology work, and to provide a forecast of future capabilities. The years shown on each Technical Objectives table approximate key aspects of the PPBES process timetable. FY97-98 relates to the budget years. FY99-03 addresses the POM time period, and FY04-12 covers the Army RDA Plan. The Army Science and Technology Objectives (STOs) that are associated with this chapter can be found in Volume II, Annex A, of this plan.

C. Aerospace Propulsion and Power

1. Scope

Advanced propulsion and power technologies provide the muscle for Army land combat systems. Toward this end, the Army aerospace propulsion and power technology area focuses on technologies that will result in aircraft and missile propulsion systems and components, including prime power transmission, that are more compact, lighter weight, higher horsepower, more fuel efficient, and lower cost than those currently available. It also focuses on compact, lighter weight, lower cost, and longer duration aircraft and space vehicle power generation systems and their components. In addition, it includes associated fuels and lubricants. It excludes efforts directed toward generic materials, which are included in Materials, Processes and Structures, and moderate- to large-scale manufacturing process development, which is included in Manufacturing Science and Technology. Missile propulsion is discussed in Section I, *Conventional Weapons.*

2. Rationale

Aerospace propulsion and power technology will provide mobility for next generation Army aircraft and missiles and upgrades to current systems. These systems, coupled with modern doctrine, tactics, and training, will provide our soldiers the capabilities needed to execute precision strikes, to dominate maneuver battles, and to project and sustain combat power.

Army aerospace propulsion and power technology is developed jointly and in close coordination with the other military services, the National Aeronautics and Space Administration (NASA), and industry, thus inherently promoting dual use technologies and processes. As a result, both civilian industry and the military industrial base are strengthened and development is faster, more efficient, and less costly. In-house Army laboratory expertise is needed to ensure that those technologies pertinent to Army requirements are addressed, and to enable the Army to be a smart buyer and to perform the high risk technical investigations, research, and development that ensure attainment of Army requirements. The overall cost to the taxpayer for joint ventures having both military and civilian applications is therefore minimized.

3. Technology Subareas

a. Rotorcraft Propulsion

Goals and Time Frames

In the gas turbine area, under the Integrated High Performance Turbine Engine Technology (IHPTET) program, the Army, other Services, National Aeronautics and Space Administration (NASA), Defense Advanced Research Projects Agency (DARPA), and industry are working together to reduce specific fuel consumption by 40 percent and to increase the power-to-weight ratio by 120 percent of future (compared with current) engines by FY03. This enhanced propulsion capability will significantly improve Army rotorcraft range and payload characteristics starting in the year 2000 and beyond. IHPTET technology will also be applicable for ground vehicles. An "Advanced Concepts (or IHPTET IV)" activity has also begun with the goal of defining the path for gas turbine propulsion technologies and challenges beyond IHPTET Phase III.

b. Progress and Plans

Gas Turbine Engine Technology

Typically, turbine rotors use the "fir-tree" method for the blade/disk attachment. However, by employing an integrally bonded blade/disk rotor, the disk material in the "dead" rim can be eliminated, significantly reducing disk weight. Under the Low Inertia Turbine Program, AlliedSignal has fabricated an integrally bonded rotor consistent with the JTAGG II/IHPTET Phase II goals (STO IV.C.1). Design bond strength requirements have been successfully demonstrated in an 1100 F-spin test. Minor modifications have been made to improve the bonding process, and another rotor will be fabricated and spin pit tested in 1Q FY97. This is the attachment configuration for the JTAGG

II HPT which, upon successful completion, will reduce the risk of incorporating this technology into the gas generator.

Rotorcraft Drive Technology

Spiral-bevel gears (SBGs) are used extensively in rotorcraft applications to transfer power and motion through nonparallel shafts. While SBGs have had considerable success in these applications, they are a major source of vibration in gearboxes, and thus a main source of cabin noise. An analytically based optimal design tool was developed which modifies the gear tooth profile to minimize SBG noise and vibration. Advanced design spiral-bevel gears were tested, including configurations with increased fillet radius to reduce tooth bending stress, modified tooth geometry to reduce noise, and provisions to reduce premature contact and eliminate wear problems. In FY96, an optimum design was fabricated and tested. The test demonstrated more than a 50 percent decrease in gearbox vibration and over 10dB in noise reduction.

Major Technical Challenges

In order to reduce fuel consumption, turbine engine thermodynamic efficiency must be increased. Meeting IHPTET goals will require cycle temperatures near or equal to stoichiometric combustion conditions. If the engine power-to-weight ratio is to be increased, materials must be found that can survive substantially higher operating temperatures, approaching 1900°C (3500°F) in the combustor and turbine, and withstand a 280°C (500°F) increase over present levels in the compressor while retaining required mechanical strength. In addition, methodologies must be developed and validated for the design of more highly loaded aerodynamic components, allowing lower parts counts. And drive train research must be performed to lower weight, volume, noise, and durability barriers. Specific technical challenges are highlighted below.

(1) Gas turbine engine technology

- High temperature, light weight materials including metal matrix composites (MMCs) and ceramic matrix composites (CMCs)
- Efficient, highly loaded, wide range compressors and turbines
- High temperature, high speed, high pressure engine mechanical components (e.g., bearings, seals, gears)
- Computationally efficient, experimentally validated advanced design codes

(2) Rotorcraft drive technology

- Lightweight, high strength, tribologically robust gear materials
- Accurate dynamic, noise and life prediction codes
- Minimum lubricant weight designs
- Efficient, lightweight, high power density electric drive components

c. Fuels and Lubricants

Goals and Time Frames

In the fuels and lubricants sub-subarea, the Army's major thrust is in the development and demonstration of new analytical technologies by 1997 for rapid assessment of petroleum quality using spectroscopic and chromatographic methods. The technology being developed will be incorporated into the Army's new Petroleum Quality Analysis system.

Major Technical Challenges

The new analytical methods will enable a significant reduction in the operational requirements for petroleum testing in the field (i.e., 50 percent less manpower, 70 percent reduced testing time, and 60 percent less test hardware). The technical challenges encompass compressing the testing time, developing improved detection systems, correlating testing results, and developing expert systems.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Aerospace Propulsion and Power is shown in Table IV-C-1, below.

Table IV-C-1. Technical Objectives for Aerospace Propulsion and Power

Technology Subarea	Near-Term FY97-98	Mid-Term FY99-03	Far-Term FY04-12
Small Turbine Engines	• High efficiency, high pressure ratio, dual alloy centrifugal impellers. • Characterize start up process of non-traditional compression system. • Non-intrusive ignition. • Turbines with high cooling effectiveness airfoils bonded to PM disk. • Flight weight magnetic bearing control. • Non-metallics for combustor and turbine applications. • 3.5 MDN ceramic steel roller bearings. • OCRs supported: CSS 17; DSA 01, 01; DBS 23, 24, 25; MTD 03, 04; EEL 16, 18.	• Higher temperature inter/non-metallics for turbine and combustors. • Stability enhancement/active surge control concept demo. • Alternate compression system demonstrated. • Metal matrix composites for compression systems application. • Wide operating range, low pattern factor combustion system. • >1000°F magnetic bearing. • Non-traditional seals. • High torque/stiffness PT shaft. • OCRs supported: CSS 17; DSA 01, 02; DBS 23, 24, 25; MTD 03, 04; EEL 16, 18.	• Unconventional compression, combustion, power producing systems, and arrangements. • Smart engine concepts demonstrated. • OCRs supported: CSS 17; DSA 01, 02; DBS 23, 24, 25; MTD 03, 04; EEL 16, 18.
Rotorcraft Power Transfer Systems	• Hardened/ground face gears life and reliability data documented. • Completed seeded fault diagnostic/prognostic spiral-bevel gear tests. • OCRs supported: CSS 17; DSA 01, 02; DBS 23, 24, 25; MTD 03, 04; EEL 16, 18.	• High speed gearing thermal behavior validation tests. • Efficient electric component demo. • High temperature-lightweight lube system. • Low noise/lightweight planetary gear system. • OCRs supported: CSS 17; DSA 01, 02; DBS 23, 24, 25; MTD 03, 04; EEL 16, 18.	• Nonferrous, hybrid gear and shaft systems. • Electric power transmission feasibility demo. • OCRs supported: CSS 17; DSA 01, 02; DBS 23, 24, 25; MTD 03, 04; EEL 16, 18.
Fuels and Lubricants	• Develop field supportable, fast fuel quality analyzer. • OCRs supported: CSS 18, 20; DSA 22; DBS 23; EEL 19; MTD 03.		

D.

Air and Space Vehicles

1. Scope

DoD has assigned the Army as the lead for Rotary Wing science and technology in the areas of aeromechanics, flight control, structures, and subsystems supporting development of military rotary-wing air vehicles. The Aviation community is aligning all planning documents to coincide with the DoD (DDR&E) requirement to establish technology objectives, identify technical barriers, and establish milestones for achievement. Programs will be tracked by OSD to these detailed plans. The rotary-wing vehicle sub-area is divided into the following four technology efforts: aeromechanics, flight control, subsystems, and structures. The Goals objectives for each technology effort and the time frames for accomplishing them have been set in accordance with the DDR&E document entitled "Rotary Wing Vehicle (RWV) Technology Development Approach (TDA)" and are summarized below.

2. Rationale

Rotorcraft have become critically important members of the combined arms team, bringing a degree of deployability, mobility, lethality, and sustainability to the battlefield commander not available with other systems. With the continuing decrease in fiscal resources, affordability and dual use have become increasingly important in shaping Army Aviation's S&T strategy. Technology must support solutions to real world problems, avoiding work which does not provide leap ahead improvements in system capabilities. This is important to the sustainment of current systems, as the fielding of new systems is being pushed further to the "out years." From a dual use perspective, civilian and military Rotorcraft communities have a mutual stake in all but few areas of rotorcraft technology research, such as the work being done to reduce the vulnerability of rotorcraft in battlefield environments. Improvements in handling qualities, vibration, and sound level reductions are equally important to civil and military rotorcraft operators. It is estimated that 95 percent of the DoD investment in rotary-wing technology has civil application.

3. Technology Subareas

a. Aeromechanics

Goals and Time Frames

Work in aeromechanics technology addresses efforts in multidisciplinary phenomena including acoustics, aerodynamic performance, rotor loads, vibration, maneuverability, and aeroelastic stability. Aeromechanics science and technology seeks to improve the performance of rotorcraft while reducing the noise, vibrations, and loads inherent to helicopter operation. Efforts are focused on refining analytical prediction methods and testing capabilities, on improving the versatility and efficiency of modeling advanced rotorcraft, and on achieving dramatic advances through concept applications. Attaining the goal of a "jet-smooth ride" in helicopters will greatly enhance public acceptance, along with providing quieter rotorcraft. The goals set at component level are focused on reducing vibratory loads 33 percent to 53 percent, reducing vehicle adverse aerodynamic forces 10 percent to 20 percent, increasing the maximum blade loading 15 percent to 25 percent, increasing the rotor aerodynamic efficiency 5 percent to 10 percent, reducing acoustic radiation 4dB to 7dB, increasing rotor inherent lag damping 50 percent to 100 percent, and increasing the accuracy of aeromechanics prediction effectiveness 74 percent to 84 percent. The span of time set for accomplishing these goals runs from the present through the year 2011 with an intermediate milestone at year 2004. These goals and associated milestone are in tabular form following.

Goals	Improvement (%)	
	By 2005	By 2012
Reduce vibratory loads	33	53
Reduce vehicle adverse aerodynamic forces	10	20
Increase maximum blade loading	15	25
Increase rotor aerodynamic efficiency	5	10
Reduce acoustic radiation	4 dB	7 dB
Increase rotor inherent lag damping	50	100
Accuracy of aeromechanics prediction effectiveness	74	84

Major Technical Challenges

- The inability to accurately predict and control stall and compressibility characteristics of current airfoils and their impact on unsteady loads and the resulting structural dynamic responses.

  Approach—Investigate the influence of airfoil profile on development of dynamic stall in compressible flow; quantify influence of compressibility on flow control techniques; develop innovative ways to use smart materials for flow control and structural response.

- The inability to accurately predict and control forces caused by viscous and interactional aerodynamics and separated flow.

  Approach—Enhance flowfield visual techniques using Doppler Global Velocimetry; study various models' rotor wake and fuselage pressure distributions using Isolated Rotor Test System. Calculate adverse forces using validated Computational Fluid Dynamics (CFD) and comprehensive analyses.

- The inability to accurately predict and control stall and compressibility characteristics of current airfoils along the span of the rotor blades and their impact on blade loading limits. The inability to markedly increase maximum outboard blade lift coefficients.

  Approach—Develop high dynamic-lift stall-free airfoils with multi-element concepts such as slat, slots, variable leading edges, or boundary layer controls.

- The inability to accurately predict and control forces caused by viscous aerodynamics and separated flow.

  Approach—Develop reliable, validated engineering computational codes based on full-potential, vortex embedding techniques to predict rotor performance and loads in all flight regimes.

- The inability to predict and control the effect of the rotor wake and blade response on unsteady aeroacoustic loads. Controlling compressibility effects on advancing-blade acoustic sources and propagation phenomena is hampered by the interdependence of numerous parameters which influence noise radiation.

  Approach—Develop verified CFD code to predict wake geometry, airloads, and performance for rotor blades, in particular blade-vortex interaction regimes and the resulting aeroacoustics.

- Identifying successful combinations of aeroelastic rotor couplings to increase damping. The constraints include conflicting design requirements, rotary-wing operating regime diversity, and fail-safe reliability requirements.

  Approach—Investigate kinematic and smart structures couplings which result in less dependency on separate damping devices. Utilize parametric rotor testing to substantiate prediction fidelity of marginally-damped rotor configurations.

- The lack of solution to the multidisciplinary rotorcraft system phenomena. Significant difficulty of acquiring high-quality correlation data for validation. Prediction-to-design interface inadequate for complex rotorcraft synthesis.

  Approach—Prediction effectiveness attributes defined and composed against data to determine element accuracy. Metrics for improvement shall include quantifiable subelement effectiveness and system integration value, such as in a product and process development simulation.

b. Flight Control

Goals and Time Frames

Flight control technology defines the aircraft flying qualities and pilot interface to achieve desired handling qualities in critical mission tasks, synthesizes control laws that will facilitate a particular configuration achieving a desired set of flying qualities, and integrates advanced pilotage systems to the aircraft. Helicopters are inherently unstable, nonlinear, and highly cross coupled. As with many other technologies, the revolution in the power and miniaturization of computers holds tremendous promise in this field, permitting realization of the full potential of the rotorcraft's performance envelope and maintenance of mission performance in poor weather and at night.

Through the integration of the vehicle's flight control system with weapons fire control, a 60 percent improvement in the pointing accuracy by the turn of the century will permit increased use of low-cost, unguided rockets as precision munitions. Further, a significant development cost driver is being assessed. Objectives have

Goals	Improvement (%)	
	By 2005	By 2012
Improve external load handling qualities at night	CHPR 4	CHPR 3
Improve external load handling qualities with partial actuator authority	CHPR 4	CHPR 3
Reduce the probability of encountering degraded handling qualities due to flight control system failures	50	90
Improve weapon-platform pointing accuracy techniques	60	80
Increase exploitable agility and maneuverability	10	15
Reduce flight control system flight test development time	30	50

CHPR = Cooper Harper Pilots' Rating

been set to improve external load handling qualities at night and with partial actuator authority each from a Cooper Harper Pilot's Rating (CHPR) of 4 to 3, reducing the probability of encountering degraded handling qualities due to flight control system failures 50 percent to 90 percent, improving the weapon platform pointing accuracy techniques 60 percent to 80 percent, increasing exploitable agility and maneuverability 10 percent to 15 percent, and reducing flight control system flight test development time from 30 percent to 50 percent. Time span for accomplishment is from the present through year 2011 with an intermediate milestone at year 2004. These goals are quantified in the table above.

Major Technical Challenges

- Lack of knowledge of optimal rotorcraft response types (rate, attitude command/attitude hold, translational rate command) and their interactions with load suspension dynamics and load aerodynamics.

  Approach—Use piloted simulation and flight test to investigate handling qualities requirements for external loads. Develop appropriate criteria for poor weather and darkness. Extend efforts to address high speed flight and loads with significant aerodynamic interactions.

- Lack of techniques for sensing the onset of limits, determining appropriate actions, and cueing the pilot or generating automatic interference to permit the pilot to safely, but aggressively, fly the rotorcraft out to the limits of the flight envelope.

  Approach—Use analysis and piloted simulation to develop techniques for protecting the pilot from loss of control and avoiding catastrophic failures or reduced fatigue life. Validate critical concepts in-flight using variable stability helicopter.

- Inadequate air vehicle mathematical modeling and Flight Control System (FCS) design, optimization, and validation techniques. These deficiencies prevent achieving desired handling qualities for advanced configurations and critical mission tasks, without time consuming iteration during flight test.

  Approach—Improve mathematical modeling and simulation fidelity so that new aircraft actually fly as designed. Improve techniques for updating math models and control laws to minimize time required to diagnose and eliminate deficiencies. For advanced fly-by-wire flight control systems develop simpler redundancy management and software V&V techniques so that time for making changes can be reduced.

- Lack of knowledge of optimum functional integration of flight controls, engine fuel control, the weapon systems, and the pilot interface.

  Approach—Develop a viable Integrated Fire and Flight Control (IFFC) system architecture; conduct manned full-mission simulation, ground demonstration of hardware and software for airborne vehicle application; and flight test demonstration of the IFFC concept.

c. Structures

Goals and Time Frames

Focusing on Integrated Product and Process Development (IPPD), rotary-wing structures science and technology aims at improving aircraft structural performance while reducing both acquisition and operating costs of the existing fleet of aircraft and future systems. The technical feasibility of load synthesis methods (holometrics, et al.) and regime/flight condition recognition algorithms as means to predicting the actual loads experienced in-flight has been demonstrated; further improvements to the reliability of these methods will enhance the safety, performance, and cost effectiveness of rotorcraft. "Virtual prototyping" of systems to optimize the structural design for efficiency and performance will remove a large portion of the risk in exploring new concepts and rapidly move the most promising concepts to production.

Goals	Improvement (%)	
	By 2005	By 2012
Increase accuracy of in-flight cumulative fatigue damage prediction techniques	95	98
Reduce recurring production labor hours by weight for composite structures	25	40
Increase airframe structural efficiency	15	25
Increase displacement capability of smart materials actuators	300	500
Increase accuracy of structural loads prediction	75	85

Objectives have been established for the 2004 and 2011 timeframes, relating to increasing the accuracy of in-flight cumulative fatigue damage prediction techniques by 95 percent and 98 percent; reducing the production labor hours per pound for composite structures by 25 percent and 40 percent; increasing airframe structural efficiency by 15 percent and 25 percent; increasing the displacement capability of smart materials actuators by 300 percent and 500 percent; and increasing the accuracy of structural loads prediction by 75 percent and 85 percent.

Breakthroughs in these areas will effect improvements in maintenance and production costs, as well as reduce the empty weight fraction of the airframe while increasing durability, performance, and ride comfort of rotorcraft. Selected examples follow: The development of composite tilt rotor blades and testing of these in a transonic dynamics tunnel in FY95-96; piezoelectric interior noise reduction for rotorcraft hubs, in FY96; and validate stress and failure analysis based on inspection model for structural integrity.

Major Technical Challenges

- Lack of knowledge and accurate methodologies for flight regime recognition algorithms for determining the rotorcraft flight conditions from state parameters in a dynamic environment. Lack of knowledge and accurate methodologies for the synthesis of strains/loads from other measured parameters and loads in a dynamic environment. Limited fatigue life and durability of load/strain measuring sensors in a dynamic operational environment.

  Approach—Develop and refine flight regime/flight condition recognition and load synthesis algorithms based on aircraft state parameters and other measured loads. Conduct bench and flight test evaluations on instrumented aircraft to validate accuracy. Collect operational data over a period of 1-3 years to validate the reliability of the flight data recorder and the algorithms.

- Lack of knowledge of accurate algorithms for determining the rotorcraft flight condition from state parameters in a dynamic environment.

  Approach—Develop and refine regime/flight condition recognition algorithms based on aircraft state parameters. Conduct bench and flight test evaluations on instrumented aircraft to validate accuracy. Collect operational data over a period of 1 to 3 years to validate the reliability of the flight data recorder and regime/flight condition recognition algorithms.

- Inability to sense and measure rheological behavior of materials during cure; lack of optimization techniques to minimize scrap; insensitivity of embedded sensors for adaptive control of cure cycle; lack of defect characterization and impact on structural performance; lack of process simulation models; ineffective application of automated fiber placement/ply handling methods to lean manufacturing; inability to measure bond integrity.

  Approach—Design and fabricate representative components to demonstrate advanced manufacturing technologies and tooling techniques. Investigate manufacturing process simulation models through cure prediction, cure cycle optimization, and structural testing to validate cure cycle optimization and structural efficiency. Demonstrate the use of embedded sensors for adaptive control of the cure cycle through fabrication and test of representative rotorcraft components. Develop and demonstrate the use of nondestructive inspection techniques for determining the integrity of bonded structures.

- Lack of knowledge and understanding regarding multi-disciplinary design, control of rheological properties during curing, static and fatigue strain limits, fiber marcelling during braiding and weaving, and innovative configurations and concepts tailored to advanced materials applications.

  Approach—Develop innovative structural design configurations using advanced materials tailorable for structural efficiency. Develop and demonstrate representative rotorcraft structures using IPPD to optimally meet multi-disciplinary design requirements which include cost, weight, performance, and reliability. Fabricate structural components in sufficient quantities to validate the quality, manufacturing repeatability, structural efficiency, and recurring cost. Develop and demonstrate advanced braiding and weaving equipment and methods to minimize fiber breakage and marcelling. Fabricate structural preforms and incorporate these preforms into tailored structural fittings and components to validate the structural efficiency and recurring costs.

- Limited displacement capability, limited force capability, limited high cycle fatigue life, and high power requirements of existing smart materials.

  Approach—Investigate the force, displacement and poor requirements of new and emerging smart materials for advanced rotor actuation methods; conduct trade-off analyses; demonstrate smart materials applications to rotor actuators through laboratory testing in a dynamic environment.

- Inability to model and analytically predict the rotating and fixed system structural loads and the interaction of those loads with the vehicles aerodynamic environment. Inability to conduct detailed stress analyses of complex components under large deformations in a timely manner to support IPPD. Inability to accurately predict crushing loads and behavior of airframe structures in a dynamic crash environment.

  Approach—Develop and validate enhanced comprehensive methods that incorporate multi-disciplinary technology based on finite element techniques that include composite structures modeling, specifically concentrating on the rotor system loads and aeroelastic stability analysis. Develop and validate reliable finite element analysis modeling and simulation techniques that include large strain effects required to model the energy absorbing characteristics of crushable composite structures.

d. Subsystems

Goals and Time Frames

Rotary-wing Vehicle subsystems encompass a broad range of science and technology topics related to the support, sustainment, and survivability of increasingly complex aircraft systems, and to the unique problems associated with the application of high performance weapons on rotorcraft. In addition to addressing affordability issues for operation and support (O&S) costs, this area also encompasses the extension of the useful life of weapon systems through upgrading armament and other mission equipment. Five key technological objectives have been established for the 2004 and 2011 timeframes: increasing the probability of detecting incipient mechanical component failures to 90 percent and 95 percent, increasing hardening to threats by 20 percent and 35 percent, reducing radar cross section (RCS) by 25 percent and 40 percent, reducing infrared (IR) signature by 35 percent and 50 percent, and reducing visual and electro-optical signature by 35 percent and 55 percent. Attainment of these goals will translate to aircraft which will be able to operate with fewer maintenance hours per flight hour, and operate safely and effectively in a hostile environment.

Goals	Improvement (%)	
	By 2005	By 2012
Reduce radar cross section	25	40
Reduce infrared signature	35	50
Reduce visual & electro-optic signature	35	55
Increase hardening to threats	20	35
Increase probability of detecting incipient mechanical component failures	90	95

Major Technical Challenges

- Modeling and analytical predictions for characterization of component materials and integration concepts performance in signature suppression.

  Approach—Conduct computer modeling from signature prediction to battlefield simulations. Conduct laboratory and flight testing of cost-effective attenuating materials and design concepts that will reduce IR, RCS, acoustic, visual, and electro-optic emissions from rotorcraft.

- Modeling and analytical predictions for characterization of component materials and integration concepts performance in hardening.

  Approach—Conduct computer modeling of hardening concepts to provide reduced probability of kill across the full spectrum of known threats, as well as crash impacts.

Conduct demonstrations of components and of the integration of lightweight armor, DEW, and NBC hardening that balance cost, weight, and effectiveness.

- Lack of reliable, rugged, cost-effective, nonintrusive monitoring techniques, sensors, algorithms, and methods.

  Approach—Develop a quantified database of the performance of impending component failures. Conduct laboratory and field testing of advanced sensors and monitoring systems.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Air Vehicles is shown in Table IV-D-1, below.

Table IV-D-1. Technical Objectives for Air and Space Vehicles

Technology Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Aeromechanics	• Aeroacoustic and aeroelastic prediction codes verified and incorporated in comprehensive analysis. • Rotor/fuselage interaction CFD-unique experiments. • High-lift rotor concepts evaluated. • Low-cost high efficiency rotor design methodology initiated. • CFD/inflow analysis verified. • OCRs supported: CSS 05, 11, 12; DSA 01, 03, 21, 22; DBS 22, 23, 24; MBS 09, 25, 29; EELS 18, 20, 26.	• Reduce critical unsteady loads by 50%. • Reduce vehicle parasite drag by 15%. • Increase in maximum blade loading by 15%. • Increase in rotor lift/drag by 8%. • Increase in rotor Figure of Merit by 7%. • OCRs supported: CSS 05, 11, 12; DSA 01, 03, 21, 22; DBS 22, 23, 24; MBS 09, 25, 29; EELS 18, 20, 26.	• Reduce by 75%. • Reduce by 30%. • Increase by 25%. • Increase by 15%. • Increase by 12%.
Flight Control	• Establish cargo/slung load flight test maneuvers; conduct simulations to develop criteria for hover and low speed. • Complete terrain correlated turbulence model. • Develop and transition advanced control law synthesis techniques. • Complete CIFER UNIX upgrade and train industry. • Complete IFFC piloted ground simulations. • Develop techniques for pilot-envelope cueing and limiting. • OCRs supported: CSS 05, 11; DSA 01, 02, 05, 27; DBS 11, 12, 22, 23, 24; MBS 09, 25, 29; EELS 01, 02, 03, 20, 22.	• Improve slung load handling qualities to a CHPR of 4. • 70% increase in bandwidth while maintaining gust rejection capability. • 60% improvement in weapon-platform pointing accuracy techniques. • 66% reduction in envelope maneuvering margins. • OCRs supported: CSS 05, 11; DSA 01, 02, 05, 27; DBS 11, 12, 22, 23, 24; MBS 09, 25, 29; EELS 01, 02, 03, 20, 22.	• Improve CHPR to 3. • 80% increase in bandwidth. • 80% improvement. • 75% reduction in envelope maneuvering margins.

(Continued)

Table IV-D-1. Technical Objectives for Air and Space Vehicles (Continued)

Technology Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Structures	• Define RWST structured configuration, requirements. • Select critical components for development, testing and demonstration in RWST. • Complete fabrication and testing of RTM trial beam for RAH-66, TP horizontal stabilizer for OH 58D, and TP tailboom section for the RAH-66 baseline. • Develop system architecture for MATES and prliminary design concept for damage tolerant hub fixture for RAH-66 baseline. • Initiate the harmonization of civil and military design requirements, specifications, standards, and the application and refinement of IPPD principles to reduce life cycle costs. • OCRs supported: 05, 11; DSA 01, 02, 05, 22; DBS: 11, 12, 22, 23, 24; MBS: 09, 25, 29; EELS 01, 02, 03, 20, 22.	• 95% accuracy for loads synthesis. • 98% accuracy with flight regimes recognition algorithms. • 30% reduction in recurring production labor hours per pound for composite structures. • 200% increase in displacement capability of smart materials actuators. • OCRs supported: 05, 11; DSA 01, 02, 05, 22; DBS: 11, 12, 22, 23, 24; MBS: 09, 25, 29; EELS 01, 02, 03, 20, 22.	• 98% accuracy for loads synthesis. • 50% reduction in recurring production labor hours per pound for composite structures. • 400% increase in displacement capability of smart materials actuators. • 35% increase in structural efficiency.
Subsystems	• 100% probability of detection of impending failures of structural components. • 20% increased operational durability and repairability of reduced signature materials. • 15% reduction in infrared and visual electro-optic vehicle signatures. • 10% increase in ballistic and NBC hardening technique. • OCRs supported: BC 05, 08; CSS 26, 28; MBS 09, 11, 17, 22, 26.	• 30% reduction in signatures. • 25% improvement in hardening techniques and concepts. • 95% probability of detection of impending component failures. • OCRs supported: BC 05, 08; CSS 26, 28; MBS 09, 11, 17, 22, 26.	• 35% reduction in signatures. • 30% improvement in hardening techniques and concepts. • 98% probability of detection of impending component failures.

E.

Chemical and Biological Defense (CBD) and Nuclear

1. Scope

The National Defense Act for FY94, Public Law 103-160, consolidated management and funding of both medical and non-medical CBD programs under OSD and in separate Defense accounting lines. The law designated the Army as executive agent to coordinate and integrate the CBD acquisition program. In that capacity, the Army has elected to present the CBD Program in this S&T Master Plan. The non-medical CBD programs are discussed here in Section E, while the medical CBD programs are addressed in Section Q, *Medical and Biomedical S&T.*

The Chemical and Biological Defense and Nuclear program includes those technology efforts that maximize a strong defensive posture in a nuclear, biological, or chemical environment using passive and active means as deterrents to the use of weapons of mass destruction. These technologies include the areas of hardening electronic components against the radiation, blast, thermal, and electromagnetic pulse effects of tactical nuclear weapons; chemical and biological detection; information assessment, which includes identification, modeling, and intelligence; contamination avoidance; protection of both individual soldiers and equipment; and collective protection against weapons of mass destruction.

2. Rationale

Defense against nuclear, chemical, and biological agents is accomplished at several levels: enhancing survivability of land combat systems and helicopters, detecting CB agents before personnel are exposed, protecting personnel once agents are employed, decontaminating following exposures, and providing safe and effective medical countermeasures. Related areas include modeling and simulation of agent characteristics and modernizing armored systems for nuclear, chemical, and biological survivability.

3. Technology Subareas

a. Electromagnetic Environment Survivability

Goals and Time Frames

Electromagnetic environments (EMEs) result from a variety of sources, including low and high altitude electromagnetic pulse (EMP) from nuclear weapons. The EMP environments, in conjunction with the other EM environments, are being studied to determine undefined aspects that could induce unexpected systems vulnerabilities in an electronic battlefield. Once vulnerabilities are determined through validated simulation analysis and measured assessments, recommendations and guidelines are developed to increase the survivability of the electronic equipment. Areas of concentrated effort will be translating source region EMP code for execution on a desktop computer, characterizing a terminal protection device, and developing a simple code for predicting output from asymmetric nuclear weapons (FY97).

- Evaluate, develop, and leverage EMP research on related EM effects that will ensure that ARL's technology development resources are focused on the advancement and survivability of electronic battlefield systems (FY98).

The requirement for weight reduction in tactical weapon systems will result in an increased use of nonmetallic structures. Composites and other advanced nonmetallic materials are being evaluated for EM protection for the electronic battlefield. Refined EM modeling of a Comanche helicopter mock-up will include composite surfaces (FY97).

- Include full anisotropic materials in the 3-dimensional time domain finite difference models for composite structure used in EM modeling (FY98).

Major Technical Challenges

The major technical challenges will be to model the effects of EMP from a high or low altitude burst of a nuclear weapon. Additional challenges are to validate EM modeling with measurement techniques that will lead to a wide spectrum of EM protection that can be leveraged.

- Develop computer simulation model to evaluate the EMP threat to existing weapons systems, and to evaluate the EMP protective effects of composite materials.
- Apply EMP shielding principles to designs for retrofit of existing vulnerable electronics, and to leverage EMP research for application into a variety of EM environments.

b. Radiation, Blast, and Thermal Protection

Goals and Time Frames

Ionizing radiation from tactical nuclear weapons will disrupt theater operations by affecting both crews of armored vehicles and electronic systems. Evaluations are performed to develop and recommend methodologies that will enhance the survivability of crew-served vehicles and on-board electronic systems. Analysis will be performed on the initial shielding design of CRUSADER (FY97) and will be begun on advanced Army vehicles (FY98). Test methodologies are enhanced or developed to evaluate the radiation effects on advanced electronics to include complex microprocessors (IDT 4600/4700 and Power PC) and memory circuits (Ferroelectric Random Access Memories) (FY97). Silicon carbide MOSFETs are also being evaluated for radiation tolerance in a high temperature environment (FY97). In addition, evaluation of changes in commercial processing of radiation-hardened CMOS electronics is continuing (FY97–FY98).

Nuclear air blast overturns vehicles and associated support systems and therefore poses a problem with current concepts of lighter battlefield equipment. A procedure to simulate non-ideal airblast was developed and is used to research the non-ideal air blast effects on Army equipment. Data obtained from non-ideal air blast research, along with historical data from atmospheric bursts, are used to validate blast hydrocode computations and to set parameters for non-ideal blast survivability criteria (FY97, STO). The extension of this research will be to perform studies of blast and shock wave flows over various terrains (FY98).

Major Technical Challenges

The nuclear weapons effects area poses a number of major technical challenges to the Army as noted below. The problem of overcoming these challenges is compounded by a lack of influence on the semiconductor industry by Army survivability requirements which might otherwise encourage production of cost-effective radiation-tolerant to radiation-hardened components. On a different front, as the Army moves toward the development of lighter weight equipment, the increased use of composite materials has exacerbated their vulnerability of equipment to blast and thermal effects.

- Evaluate emerging semiconductor technology early in the development cycle.
- Identify and validate non-ideal airblast parameters to model effects on new equipment.

c. Detection

Goals and Time Frames

Standoff short-range CB detection is being pursued with lasers that can detect, identify, and map chemical vapors, aerosols, and liquids on the ground at ranges of 3 km. This vehicle-mounted system will operate on the move, in real time, and, more important, will be trainable to detect future agents. The longer range biological threat will be detected at ranges up to 50 km using eye-safe lasers whose enhanced imaging capability will employ polarization and multiple wavelength excitation to increase discrimination range against natural biological backgrounds (FY01). Passive technologies such as surface-excited infrared thermoluminescence, being studied for their ability to detect CB agents on the battlefield, require development of atmospheric databases, spectroscopic detection algorithms, and optical telescope designs for airborne and space platforms (FY10). These approaches are being evaluated against the use of multiple point sensors, either distributed throughout the battlespace or mounted on mobile platforms (FY02).

Because of the unique characteristics of CB agents, their physico-chemical properties must be carefully mapped to ensure detection, and a theoretical basis for detecting unknown but related agents must be developed. Infrared, visible, and ultraviolet spectroscopy, as well as mass, Raman, and laser desorption or electrospray particle trap mass spectrometry (MS), are being applied to this problem. Finally, aerosol science is providing the basis for the development of new optical methods for interrogating aerosol clouds from a distance for the purpose of detection.

Closer to the soldier is point detection. New fluorescent, acoustic, and optical biosensors are being designed for enhanced sensitivity and more flexible detection capability. Recent advances in the acceleration of the polymerase chain reaction (PCR) on a miniaturized scale now permit the exploitation of DNA probes for field detection of pathogens. A major thrust of a Defense Technology Objective (DTO) is the development of a rapid, automated field detection device based on the PCR. One key DTO is the development of recombinant antibodies to serve as the recognition element of these new biosensors (FY96). Recombinant antibodies will ultimately be designed and quickly selected from genetic "super libraries" (FY99) to have specific detection capabilities, and novel starburst dendrimers are being studied for use on tailored reactive surfaces. Another major approach to point detection is mass spectrometry, and miniature automated versions are being assessed for integration into existing CBD platforms (FY01). Of critical importance for biosensor and MS approaches is bio-aerosol sampling since characteristics (e.g., concentration of detectable units per unit volume of air) of biological aerosols differ dramatically from chemical vapors, with resulting effects on detection efficacy. (See Figure IV-E-1.)

Major Technical Challenges

In the post-World War II era, detection was a simple matter of knowing what agents potential adversaries possessed and designing analytical procedures to detect them. The proliferation of a broad spectrum of biological agents such as toxins, viruses, and bacteria, and the potential for genetically engineered pathogens have complicated this task immeasurably. The ideal detection system would operate continually in a stand-off mode and would be capable of detecting all known—and even unknown—agents.

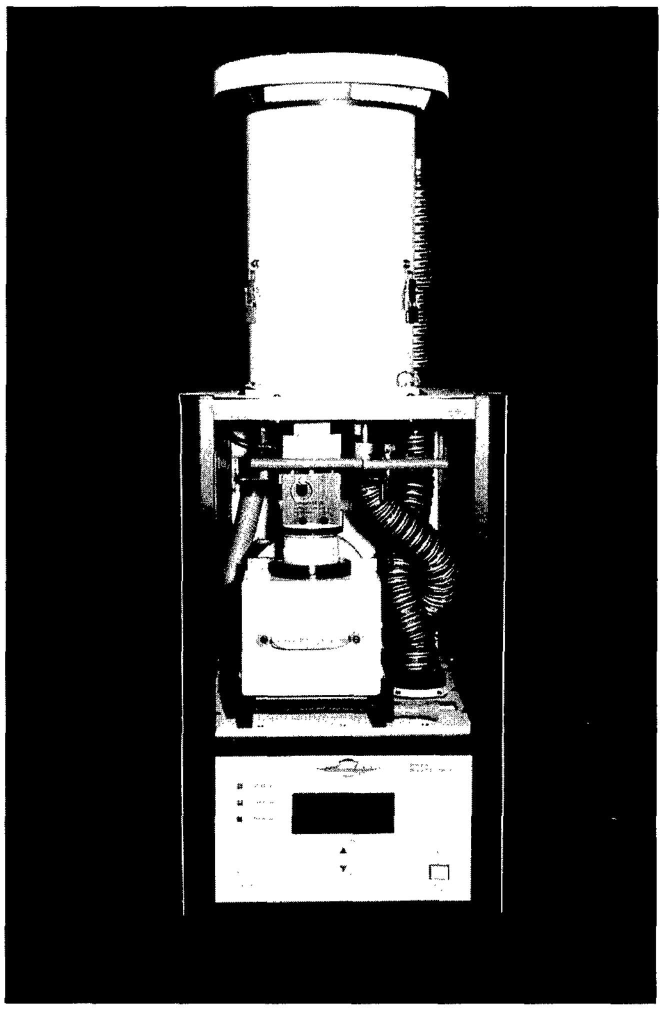
- Detection of biological weapons against a high and variable background of ambient biological material.
- Miniaturization of sensor components using nanofabrication techniques.
- Design and production of biological recognition sites such as genetic probes and recombinant peptides.
- Rapid sampling of aerosols and vapors and modeling of their behavior under different meteorological conditions.

d. Protection

Goals and Time Frames

The second major theme in CB defense is protection, and this may be divided into individual and collective protection. The foci of individual protection are to reduce the physiological burden of the protective mask and clothing, thereby reducing performance degradation; to integrate the mask into future soldier systems; and to protect against future CB threat agents. To accomplish these goals, new materials will be needed to decrease breathing resistance (FY05) and increase binocular vision (FY05). Computer-aided design and rapid prototyping techniques are being employed to both improve mask performance and manufacturing processes.

Figure IV-E-1. Soldier in Protective Garments Operating Chemical Agent Monitor



Supporting this, new physiological and protection tests are being developed. For clothing, selectively permeable and smart membranes are being assessed for enhanced protection and reduced heat stress. Selectively permeable membranes laminated to lightweight shell fabrics will provide low thermal insulation and high vapor transmission. Incorporation of reactive materials into the membrane will reduce the need for carbon and extend service life. Collective protection focuses on advanced filtration concepts that will reduce power, space, and volume and on new materials as alternatives or enhancements for existing charcoal systems. Temperature swing and pressure swing adsorption, as well as catalytic oxidation over monolithic catalysts, are under investigation in an attempt to provide filter systems that can be used over and over again (FY01). In addition, sorbents with precisely defined engineered pore structure are being investigated as replacements for the traditional activated carbon (FY10). Finally, computer models are being designed to predict filter performance characteristics from fundamental data on filtration media.

Major Technical Challenges

The major challenge will be to design new materials with both filtration and catalytic properties to protect against a broad spectrum of both chemical and biological agents, while reducing the physiological burden to the soldier.

- Desorb threat agents from filter materials in order to extend time between filter changes using temperature and pressure swing absorption.
- Develop engineered adsorbents with increased protection and decreased volume and breathing resistance.
- Use computer-aided design to evaluate performance of new filter materials and reduce test time.

e. Decontamination

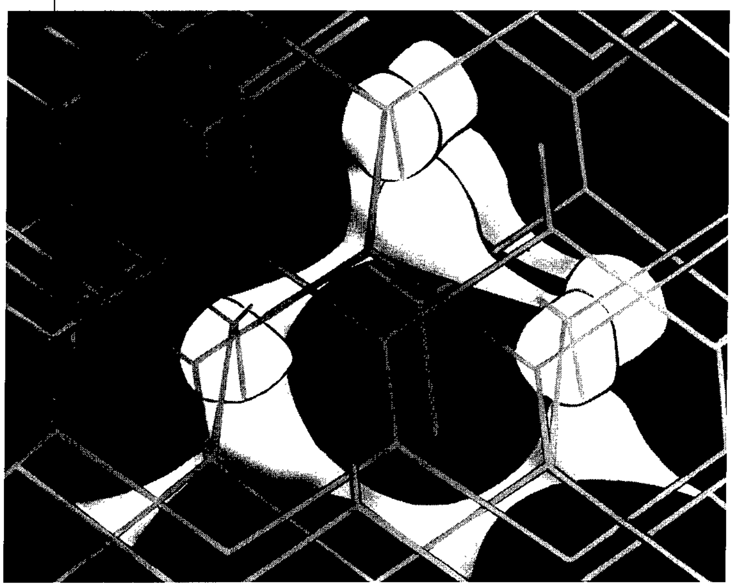
Goals and Time Frames

The third major theme is decontamination, and this can be divided into three categories: Immediate, which is carried out by the individual soldier; Operational, which is carried out by the contamination unit; and Thorough, which is performed by the chemical company, usually at an equipment decontamination site. Both hydrolytic and oxidative reactions are being studied, with the goal of formulating stable decontaminants with new reactants for rapid destruction of mustard, and V and G nerve agents. Catalytic materials such as enzymes are being designed and assessed for their ability to destroy chemical agents under mild, ambient conditions, thus avoiding damage to delicate equipment (FY96). Ultimately, these new catalytic materials may be incorporated into sorbents and self-decontaminating coatings, fibers or paints (FY10). (See Figure IV-E-2.)

Major Technical Challenges

The main technical objective is to design decontaminating materials with highly catalytic properties, long shelf life, and an ability to function under a broad range of temperatures and pH.

Figure IV-E-2. Molecular Model of Catalytic Oxidation



- Using molecular modeling and site-directed mutagenesis, design catalytic enzymes with enhanced turnover (i.e., degradative) rates and stability under various environmental conditions.
- Design and synthesize conductive polymers and finishes which incorporate catalytic enzymes or their active sites.

f. Modeling and Simulation

Goals and Time Frames

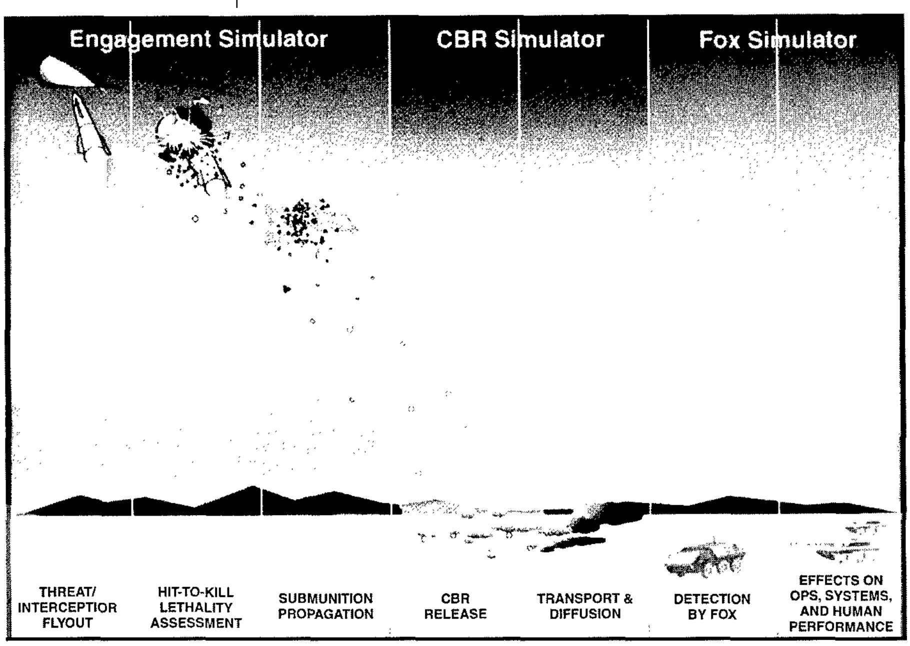
The use of modeling and simulation (M&S) is an essential aspect of the current and future CB Defense (CBD) Program. Advanced computer simulation technology will allow soldiers to be immersed in a realistic and physically accurate computer-generated combat environment which includes CB agent cloud movement and target effects under variable weather, terrain, and foliage conditions. This capability will allow the military user, for the first time, to experience the impact and consequences of CB weapons of mass destruction (WMD) in operational situations and, more important, will demonstrate the potential value of CBD equipment (FY01). Simulations of both conceptual and actual CBD equipment will result in improved and stable performance requirements to be established early in development (FY01). The Distributed Interactive Simulation (DIS) network will enable the user to evaluate the "value-added" of each CBD item at every phase of development. (See Figure IV-E-3.) By means of virtual prototyping, soldiers will contribute to the detailed design of new equipment throughout the development cycle. The combination of constructive (wargaming) and virtual (3-dimensional) simulations will permit CBD hardware performance characteristics to be optimized prior to production. Virtual prototyping will greatly decrease the acquisition time and associated costs of development including test and evaluation elements. The mutual interaction between user and developer, provided by M&S throughout the acquisition cycle, will result in superior CBD products within the limited funding and resource constraints anticipated for the future.

As the threat evolves and proliferates, it becomes increasingly important to be able to identify, synthesize, and assess the physico-chemical and toxicological properties of new compounds. These studies are being used to develop quantitative structure-activity-property relationships and, ultimately, to predict the behavior of new compounds in biosystems. Novel, short-acting sedatives are being developed from these efforts as potential less-than-lethal chemicals for a variety of applications, and candidate nontoxic simulants with reduced environmental impact are also being selected and tested.

Major Technical Challenges

There are two main objectives for M&S: first, to develop models which accurately predict the effect of CBW agents on battlefield performance, as well as the protective capability of

Figure IV-E-3. Simulation of Intercept of Chemical or Biological Agent Munition



CBW defense equipment; second, to model structure-activity relationships to predict the threat potential of new compounds and their behavior in both bio- and ecosystems.

- Develop a verifiable capability to analyze CB detectors and detection systems in existing "constructive" wargames.
- Formulate a "value-added methodology" using Distributed Interactive Simulation to assess the operational benefits of CB defensive equipment in the light-to-moderate battlefield situations.
- Enhance the display and assessment ability for tactical ballistic missile interception of CB warheads within the "virtual environment" simulation arena.
- Create a verifiable methodology, using the "VL STRACK" cloud transport and diffusion model to depict the movement of military vehicles through/around diffusing CB clouds through and around heavy foliage and wooded terrain.
- Install modules addressing CB defense functions (detection, protection, decontamination, and survivability) into Joint Service computer wargames to enhance comparative decision making earlier in the acquisition cycle.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Chemical and Biological Defense and Nuclear is shown in Table IV-E-1, below.

Table IV-E-1. Technical Objectives for Chemical and Biological Defense and Nuclear

Technology Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Electromagnetic Environment (EME) Survivability	• SREMP code modification for IBM PC. • Composite material analysis. • Terminal protection devices. • OCRs supported: BC 20; MTD 07, 12.	• Extend terrain-enhanced EMP, HEMP, and assymetric nuclear weapon effects codes. • Advance composite material analysis. • OCRs supported: BC 20; MTD 07, 12.	• Guidelines for controlling EME. • Upset mitigation technologies. • Environments from 3rd generation NWs. • OCRs supported: BC 20; MTD 07, 12.
Radiation, Blast and Thermal Protection	• Radiation response of microelectronics. • Vehicle radiation shielding code. • Measurement and simulation of non-ideal blast. • OCRs supported: BC 20; EEL 08; MTD 07.	• Formulate guidelines for assessing commercial microelectronics. • Vehicle radiation shielding code for advanced composite vehicles. • Transition data and modeling to SLAD. • OCRs supported: BC 20; EEL 08; MTD 07.	• Formulate guidelines for manufacturing microelectronics. • Develop enhanced simulation and modeling techniques. • OCRs supported: BC 20; EEL 08; MTD 07.
Detection	• Genetically engineered antibodies. • Flow cytometry as an immunoassay platform for bio detection. • OCRs supported: BC 01, 12.	• Genetic Super library. • Standoff bioagent detection at 5-50 km. • Automated single step point detection. • Subsymptomatic detection of chemicals in lightweight individual soldier detector. • OCRs supported: BC 12; DSA 05, 14.	• Lightweight C/B detection from UGV/UAV platform. • Miniaturized photo-array detection/ identification of biological agents. • OCRs supported: BC 12; DSA 05,14; MTD 07; EEL 13.
Individual Protection	• 24-hour liquid protection. • 50% reduction in breathing resistance. • Develop advanced selectively permeable membrane eliminating/ reducing the use of carbon in chemical protective ensembles. • OCRs supported: MTD 11.	• 50% increase in binocular vision. • Expanded performance degradation model. • Compatibility with future soldier systems. • OCRs supported: MTD 11.	• Full field of view through transparent face piece. • New super dense absorbents. • Smart barrier membranes. • OCRs supported: MTD 11.
Collective Protection	• Prototype Pressure Absorption System. • Lab scale Temperature Swing Absorption System. • OCRs supported: EEL 08; CSS 13.	• Combined PSA/TSA/Catox System. • Engineered absorbents. • OCRs supported: EEL 08; CSS 13.	• Monolithic filtration media. • Membrane filtration. • OCRs supported: EEL 08; CSS 13.
Decontamination	• New polymers with agent reactive sites for more efficient decon. • OCRs supported: MTD 13.	• Automatic decontamination through conductive coatings. • OCRs supported: MTD 13.	• Self-decontaminating coatings. • OCRs supported: MTD 13.
Modeling and Simulation	• Distributed interactive simulation capability for CB detectors. • OCRs supported: MTD 20.	• Upgraded wargames and virtual prototypes of CB defense equipment. • OCRs supported: MTD 20.	• Virtual reality using man-in-loop. • Virtual/actual CBD equipment in fully integrated constructive and virtual combat simulations. • OCRs supported: MTD 20; DSA 16.

F. Individual Survivability and Sustainability

The area of Individual Survivability and Sustainability in the FY96 ASTMP is now divided into two subareas under the new Human Systems area.

1. Scope

Individual Survivability and Sustainability focuses on protecting and sustaining the individual warfighter—ultimately the most critical element of any weapon system on the digitized battlefield. By providing food, drinking water, clothing, airdrop, and shelter, this technology area ensures warfighter survivability and performance and enhances readiness and quality of life on the battlefield and in operations other than war.

This technology area comprises two subareas: (1) Individual Survivability and (2) Sustainability. The Individual Survivability subarea includes all material and combat clothing systems for protection of the individual warfighter. These efforts provide technology advancements in the areas of individual ballistic protection, countermeasures to sensors, head gear and laser eye protection, multifunctional materials, and warrior performance and endurance enhancements.

The Sustainability subarea includes scientific and technological efforts to sustain and enhance warfighter performance and combat effectiveness. These range from nutritional performance enhancement, food preservation, food service equipment, energy technologies, and drinking water to advanced and precision cargo/personnel airdrop and airbeam technologies for shelters. Technologies pursued in this effort address the need to "fuel the fighter"—to deliver the right nutrients at the right levels at the right time in the right combination, to provide versatile airdrop capabilities critical to worldwide force projection and resupply, and to provide rapidly deployable shelters in forward areas.

2. Rationale for Investment

a. Relationship to Military Capabilities/Needs

Providing multipurpose protective clothing, individual equipment, rations, water, airdrop equipment, and inflatable shelters in all terrains and environments will provide the broad military capability and technological edge to rapidly respond on a global basis to a diverse variety of missions. The most significant payoffs are those which increase battlefield survivability and sustain and enhance performance. (Refer to individual subareas for more specific relationships to military capabilities.) Figure IV-F-1 depicts the four Army mission requirements supported by these subareas: (1) protective clothing and equipment, (2) rations and water, (3) air delivery systems, and (4) airbeam-supported shelters.

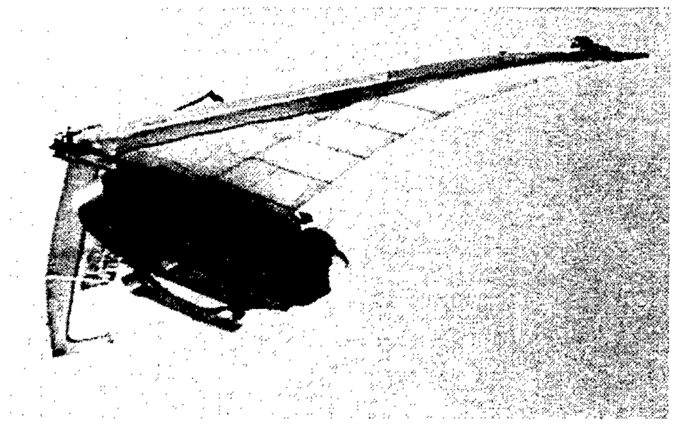
b. Technical Forecast

Foreseeable advances in individual survivability technologies include development of next generation advanced materials for multiple threat protection; technology to provide fragmentation and small arms ballistic protection at 20 to 30 percent reduced weight; materials to prevent detection by multispectral sensor devices; clothing systems that provide thermal and environmental protection with minimum bulk and weight; and development and application of integrated soldier and small unit battlefield performance simulations that support analysis of technology enhancements.

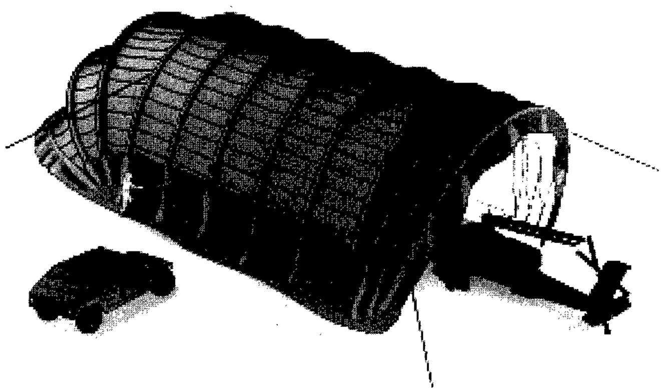
Foreseeable advances in sustainability technologies include targeted and modulated nutrient delivery for heightened mental acuity and physical performance; use of intrinsic chemical markers to validate sterility of thermally processed foods; biosensors to monitor ration deterioration; use of nonthermal processing technologies (such as irradiation or pulsed electric fields) to preserve foods; use of integral chemical heating technology in self-activating package configurations to ensure hot meals sites; use of integral power generation, advanced insulation materials, and non/low-powered generated refrigeration for rapidly deployable field kitchens; new water purification technology; prediction of parachute behavior and performance during

Figure IV-F-1. Army Mission Requirements in Individual Survivability and Sustainability

Combat warrior outfitted for the 21st century with a computer/radio, protective clothing, and individual equipment, software, integrated helmet assembly, and weapon systems.



High-Glide, Semi-Rigid Wing Air Delivery System, a high-altitude autonomously guided, offset cargo airdrop system that will minimize aircraft vulnerability to low altitude threats and enhance the rapid deployment and precision delivery of sensors and munitions.



Airbeams will drastically reduce weight, set-up time, and packed volume of current frame-supported tents. (Large Area Night Maintenance Shelter shown.)

Nutritious field rations and water fuel the combat soldier and enhance performance.

parachute opening; autonomous and precision guidance, navigation, and control for stand-off air delivery using flexible gliding wings; parachute design for manufacturability; soft landing technologies; and new textile manufacturing technology for airbeams.

c. Payoffs

Payoffs in the individual survivability area include significant casualty reduction through enhanced small arms protection; reduced detectability by both conventional and emerging battlefield sensors; individual flame, firefighting, and environmental protection through multifunctional protective materials; laser eye protective systems; development of lightweight, low power, man-portable microclimate conditioning; improved techniques for measurement and prediction of thermal performance characteristics of clothing; and helmet-mounted displays that link the individual with information, communications, and targeting systems.

In the sustainability area, payoffs include ration systems that sustain and support highly mobile, forward deployed troops and provide enhanced performance capabilities such as improved target acquisition, enhanced cognitive skills and decision making (particularly under stressful battlefield conditions), extended mission endurance, and increased alertness; improved food packaging that protects and prevents ration components from physically or microbiologically deteriorating in extreme conditions; improved food safety/stability and quality in all environments; improved fuel/energy efficiency; improved technology to provide drinking water; and operational readiness and rapid deployability. Specific payoffs in airdrop technology include the means of delivering critical equipment, personnel, and supplies with greater accuracy, safety, and precision, resulting in greatly reduced personnel airdrop injury rates and increased survivability of delivery aircraft; support to rapid force entry tactics by reducing drop zone size requirements resulting in a faster consolidation of force and allowing for just-in-time resupply of rapidly moving forces; and reduced development, testing, and procurement costs through predictive performance and design optimization modeling and virtual testing. Payoffs from pressurized airbeam technology include significant reductions in weight, set-up times, and packed volume of soft shelters for rapid deployability in forward areas.

d. Transition Efforts

Emphasis is placed on transitioning cutting edge technologies into advanced technology demonstrations and advanced and engineering development programs, and on incorporating them directly into fielded items through specification changes and product improvements. There is also extensive collaboration with industry as evidenced by current active Cooperative Research and Development Agreements (CRDAs). Although some investment is focused on military-unique applications, many of the basic clothing, food, and portable shelter technologies are inherently dual use. (Refer to the individual subareas for more specific transitions and dual use opportunities.)

3. Technology Subareas

a. Individual Survivability

Scope

The individual survivability technology subarea addresses the full range of combat, environmental, and special purpose protective materials and components. The scope of the program includes textile and composite-based material systems and design concepts for individual ballistic protection; countermeasures to sensors; multifunctional materials (to include environmental and flame/thermal protection); warrior performance and endurance enhancement; laser eye protection; and integration of soldier system modular components. Supporting technologies include bioengineered materials for protection and analytic tools with resolution to capture battlefield effects of fatigue, load, environmental exposure, hydration, terrain, and so forth.

Potential Payoffs

Impact on Military Capability

Individual survivability technology developments are high-payoff investments that support many of the JCS mission capability areas. Capabilities provided by the Force XXI Land Warrior will include integrated POS/NAV (GPS and inertial navigation); enhanced night maneuverability; and modular, lightweight, and interoperable components tailorable to mission requirements. The individual will be linked to the digitized command and control network with near-real time battlefield intelligence. Capabilities such as accurate, automated target hand-off, unexposed firing/viewing, and signature suppression/control ensure a precision strike capability at the individual combatant level. The Army/DARPA program for helmet-mounted displays will provide an integrated headgear system (for mounted crewmen) to increase situational awareness and magnify the ability to fulfill demanding operational needs. Additionally, technologies will be pursued in multiple threat protection, wireless weapons interface, small arms body armor, countermeasures to sensors, and enhanced situational awareness. To speed this process, object-oriented modeling tools are used to develop an automated environment to enhance analytic capabilities and to promote rigorous analyses of survivability and equipment alternatives and physiological performance in a hypothetical operational environment.

Potential Benefits to the Industrial Base

Dual-use applications include high-performance fibers for ballistic/blast protection for law enforcement agencies; aircraft cargo containers; use in aerospace, electronics, and automobile industries; and recreational sport applications. Flame and thermal resistant fibers have strong dual-use in firefighting applications, race car driving, industrial workwear, hotel furnishings, and piloting. The anthropometric data base/models have commercial applications in the design and sizing of clothing systems and equipment such as boots, athletic footwear, gloves, and helmets. Cooperative R&D Agreements (CRDAs) with industry and development programs with major universities are aggressively pursued. Four active CRDAs include biogenetically engineered spider silk (Hoechst-Celanese, Inc.); biodegradable materials (International Optical Telecommunications, Inc. and Zeneca, Inc.); and enzymatic synthesis of new polymers (Rohm and Haas).

Technology Development Plan

Survivability Technology Taxonomy

Ballistic protection—Research for protection against flechettes, small arms, and high velocity fragmentation and blast threats from mines and bursting munitions; *Countermeasures to sensors*—Research on textile materials for camouflage for the individual soldier; *Multifunctional materials*—Fibers, fabrics, clothing systems, and techniques for individual protection in all climates against high heat sources and flame, and across all terrains and environmental extremes, including encapsulation and water immersion. Whole body protection against lasers, microwaves, and nuclear/thermal threats; *Warrior performance and endurance enhancement*—Research and integrated application of anthropometry, biomechanics, biophysics as scientific/engineering tools. Integrated individual protective systems and mechanisms to reduce effects of physical and environmental stresses, increase mobility, increase mission duration, and optimize the human/material/equipment interface; and *Laser eye protection*—Research into technologies affording protection from multiline and tunable lasers.

Major Technical Challenges/Approaches

Challenge: Development of polymeric materials for ballistic protection. *Approach*: Copolymerize high strength polymers [aramid-based, polyimide-based, and poly (para-phenylene benzobisoxazole)-based] to tailor properties specifically for improved ballistic protection. Crosslink aramid-based polymers to improve lateral properties (e.g., "through-the-thickness" yield stress and modules). Modify processing variations to produce high molecular weight polymer fibers and optimize morphology (e.g., molecular structure, crystallinity, and orientation) or fibers.

Challenge: Provide passive protection against advanced sensors without degrading current visual and near-infrared camouflage protection, while maintaining desired/required textile properties (e.g., durable, launderable, flexible, nontoxic). Countermeasures should not increase the bulk or heat stress on the soldier beyond levels imposed by existing clothing systems. *Approach*: The sensor of major importance at the present time is the thermal imager. Based on the physics of the problem, there are two approaches to solving this problem for the soldier: control the emissivity of the uniform or actually cool the soldier so that he provides a less conspicuous target to the sensor. Since a passive (not-powered), lightweight system is desired, research has concentrated on novel materials to control the emissivity without degrading fabric performance.

Challenge: Durable combat uniforms that provide protection against multiple threats, that are cost-effective, and that do not impose a heat stress penalty. *Approaches*: (1) Explore novel fibers, fiber blends, fabric constructions, and functional finishes that will provide protection against flame, environmental, and electrostatic hazards while providing visual and near-infrared camouflage protection; (2) Investigate/develop novel dyeing and finishing technology for flame resistant materials to provide an affordable, accurate, and simple means of determining a flame resistant garment's protection.

Challenge: Deposition of robust dielectric coatings on polycarbonate to block the near-IR band and a narrow line attenuator. *Approach*: Development of dielectric stacks for broadband laser protection in a joint effort with the USMC and PM-ACIS. Narrow line attenuators are being developed using eye-centered holograms. Dyes will be used for blocking the blue region of the spectrum.

Challenge: Modular performance augmenting components integrated within the fighting systems. *Approaches*: (1) Using biomechanical and mechanical engineering tools, develop an ergonomically efficient load-bearing system that is compatible with other system components, has a quick-release capability, is comfortable, reduces fatigue and localized injury, and increases mobility and combat effectiveness; and (2) Develop a boot design to reduce stress-related lower extremity injuries and enhance locomotor efficiency.

b. Sustainability

Scope

This subarea focuses on warfighter sustainment by providing high quality, nutritious rations, drinking water, advanced airdrop capabilities, and rapidly deployable food service equipment and inflatable shelters for forward areas. In the ration area, efforts focus on the unique military combat field feeding requirements not addressed in the private sector: low volume and weight, modularity, high nutrient density, storage stability under environmental extremes, and the battlefield logistics of providing hot food. Science and technology efforts include three main areas: (1) nutritional performance enhancement by formulating rations to provide energy and other essential nutrients, and to increase alertness and extend endurance in combat and in environmental extremes; (2) ration preservation and stabilization to prevent microbial, physical, and biochemical deterioration and to withstand the rigors of long-term military storage and distribution worldwide; and (3) field food service equipment and systems that are highly mobile, fuel efficient, and consistent with minimizing the logistics burden. Innovative water purification technology is being developed to provide drinking water to field troops. In the airdrop area, efforts focus on advanced and precision offset air delivery for cargo and personnel, high glide deployable wings, the integration of guidance, navigation, and control for rapid deployment and just-in-time resupply, and soft landing technologies for cargo and personnel. Inflatable airbeam structure technology, including 3-dimensional weaving and braiding, and scaling and shape definition will provide airbeam shelters for rapidly deployable forces and continuous operations of tactical rotary aircraft and combat vehicles.

Potential Payoffs

Impact on Military Capability

In the sustainability area, performance-enhancing ration components will increase the warfighter's mental acuity, physical performance, and ability to deal with battlefield stress. New thermal and nonthermal preservation and active packaging technologies will result in the capability to provide high quality rations for optimizing nutrient consumption.

A new water purification technology will be applicable to military water treatment equipment ranging from individual purifiers to division and corps level units. This new technology will meet or exceed the performance of existing reverse osmosis membranes.

Initiatives in advanced and precision airdrop technology will provide capabilities critical to both rapid worldwide insertion of CONUS-based initial forces and just-in-time resupply of rapidly moving forces. Airdrop technology also provides a low cost, highly accurate means of delivering personnel, munitions, and batteries and of emplacing sensors, which are necessary for real-time knowledge and digitization of the battlefield and for precision guided, standoff delivery to reduce the vulnerability of the delivery aircraft and crew.

Inflatable airbeam structures provide rapidly deployable shelters in forward areas for performing vehicle and aircraft maintenance in adverse environments and under blackout conditions. Also, these inflatable structures will assist in quickly establishing a presence in remote areas without adequate facilities for maintenance, storage, medical, billeting, and command and control (C2) centers.

Potential Benefits to the Industrial Base

Significant dual-use applications exist for disaster and humanitarian relief, for sports and other recreational activities (campers, backpackers, hunters, etc.), for forest fighting, and for special dietary concerns (shelf-stable flexibly packaged foods). The new water purification technology will also be applicable to municipal desalination plants.

Twelve CRDAs include the following: meals in microwave retort pouch (My Own Meals, Inc.); radiation preservation of foods (Food Technology Service, Inc.); shelf-stable breads and bakery products (Mila's European Bakery); microencapsulation of performance modifying nutrients (BioMolecular Products, Inc.); edible films (Marine Polymer Technologies, Inc.); encapsulation systems for lipids and flavors in military rations (IGI, Inc.); individual ration components for military/commercial use (M&M, Mars, Inc.); integration of hydrogen suppression material in flameless ration heater (Zestotherm, Inc., and Dynatron, Inc.); intermediate moisture foods (Good Mark Foods, Inc.); antifungal/antibacterial agent (Green Cross Corp. of Japan); and airbags as impact attenuators for airdrop soft landing (Marotta Scientific Control, Inc.). There are several CRDAs under negotiation.

While industry has assumed the lead role in applying irradiation technology, supported research, in coordination with USDA and industry, contributes directly to providing the scientific basis required for gaining regulatory approval for the use of this technology for both military and civilian benefit. Additionally, there is joint industrial collaborative research to exploit novel quality enhancement and quantification technologies, high pressure processing treatment, and ohmic processing. Using novel methodologies developed by DA, these new processes will be validated as microbiologically safe and will lead to the production for both civilian and military consumers of a wide variety of safe and appealing foods that otherwise would not be possible using conventional thermoprocessing.

Technology Development Plan

Specific sustainability technology efforts are defined by the following taxonomy: *Preservation and stabilization technologies*—Research in food science, physical chemistry, behavioral sciences, chemical engineering, and packaging, as they relate to novel food formulation, preservation, stabilization, processing, protection, and other related technologies; *Performance enhancement and nutrition technologies*—Research in food science (e.g., encapsulation, molecular inclusion), physical chemistry, nutrition, nutritional biochemistry, behavioral sciences, neurophysiology, chemical engineering, packaging, and other related technologies; *Food service equipment/energy technologies*—Research in combustion, thermodynamics, heat transfer, thermoelectric power generation, automatic control, material, and refrigeration technologies; *Water purification technology for drinking water*—Research to prove the feasibility of a technology with a 300 percent increase in operating/storage life, a 50 percent increase in water flux, and tolerance of 5 ppm chlorine when compared with conventional reverse osmosis; *Airdrop technology*—Research in designs and concepts for parachutes/gliding wings and cargo/personnel airdrop systems; aerodynamics and control of deceleration; theoretical/computational prediction and experimental determination of decelerator behavior and performance; biomechanics of parachutists; and personnel/system interfaces to improve safety and logistics; and *Airbeam technology for shelters*—Research in fibers, fabrics, fabric stress/strain properties, manufacturing technologies, coatings and concepts for airbeam structures and textile-based shelters.

Major Technical Challenges/Approaches

Challenge: Natural complexity of food systems affects the chemical, physical, and nutritional characteristics leading to undesirable changes that are often further compounded by lengthy, uncontrolled storage. *Approaches*: (1) Determine relationship between formulations/processes and glass transition temperature using dynamic mechanical analysis and electron spin resonance, and correlate results with rate of change of critical physical and chemical properties of rations; (2) Evaluate new preservation methods that produce shelf-stable foods with the taste and appearance of "home-cooked" meals; and (3) Investigate multifunctional packaging adjuvants (e.g., oxygen scavenging, antimicrobial, nutrient protection, color protection).

Challenge: Methodology to provide data needed to establish links between specific nutrient intake and performance. *Approaches*: (1) Investigate methodologies for assessing the bioavailability and actual uptake of a variety of nutrients; and (2) Develop rapid and precise methods for determining physiological availability of nutrients in rations subjected to time-temperature stresses.

Challenge: Develop a rapidly deployable field kitchen featuring advances in diesel combustion, heat transfer, integral power, and refrigeration that can produce high quality meals quickly and economically. *Approaches*: Develop integral power generation, advanced insulating materials, and non/low-powered regenerative refrigeration. Integrate these technologies within the Army Field Feeding System—Future.

Challenge: Develop new water purification technology with a 300 percent increase in operating and storage life, a 50 percent increase in water flux, tolerance to 5 ppm chlorine, temperatures up to 165°F, and pH from 5.0 to 9.5 when compared to conventional reverse osmosis membranes.

Challenge: Analysis of the transient parachute opening processes due to the complicated interaction between the flexible and porous parachute canopy fabric and its surrounding air flow. *Approach*: Numerical coupling of the air flow process and the canopy fabric requires unsteady 3-dimensional fluid/structure analysis and modeling.

Challenge. Effectively dissipate airdrop kinetic energy to provide a soft-landing capability for cargo and personnel. *Approaches:* (1) Investigate and demonstrate airbags with advanced gas injection technologies for application to heavy cargo airdrop, (2) conduct predictive performance modeling, experimentation, and demonstration of gas operated parachute retraction concepts for application to light cargo and personnel airdrop, and (3) explore new decelerator concepts that provide increased drag efficiency.

Challenge. Lower cost, lighter weight, reduced volume parachutes. *Approaches:* (1) Develop and demonstrate advanced hybrid architecture for personel and cargo parachute applications that optimize performance with minimal construction using 2-dimensional woven fabrics, and (2) Investigate and exploit 3-dimensional weaving technologies that virtually eliminate joints and seams in constructed parachutes.

Challenge: Producible, reliable airbeam fabrication. *Approaches*: Small diameter, high pressure airbeams will be demonstrated by continuously braiding and weaving a high strength, 3-dimensional fabric sleeve over an air retention bladder. Scaling parameters and airbeam structural behavior will enable fabrication for various sizes of soft shelters.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Individual Survivability and Sustainability is shown in Table IV-F-1, which follows.

Table IV-F-1. Technical Objectives for Individual Survivability and Sustainability

Technology Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Individual Survivability	• Demonstrate an improved system for protection against combined fragmentation and small arms threats, to be measured by a 20 to 30 percent reduction in areal density (weight per given area). • Finalize whole body scan protocols compatible with ANSUR 2-D database standards. • Provide modeling, simulation, and analytical tools to reduce risk of Force XXI Land Warrior program. • Demonstrate combination breathing/ cooling concept using supercritical air. • Develop a laser protective goggle that provides maximum protection from multi-line lasers. • Demonstrate an electronically driven heat pump as an effective, lightweight, low power microclimate cooling system driver. • OCRs supported: DBS 06, 08; EEL 08, 09.	• Transfer materials technology for individual countermine protective system to provide equal protection at a 35 percent reduction in system weight. • Develop Military Operations in Urban terrain (MOUT) technology insertion components. • Demonstrate a tunable laser eye-protective device incorporation NLO materials. • Develop silk-based fabric for ballistic protective applications. • Develop fully integrated soldier system analytical model. • Demonstrate prototype boot that reduces stress-related lower extremity injuries. • Establish DoD anthropometric database and develop three-dimensional computer-aided design models. • Demonstrate a non-aramid multi-functional fabric system with a 50 percent decrease in the cost of flame protection. • OCRs supported: DBS 04, 06, 08; EEL 08, 09; CSS 06, 07, 18, 20.	• Demonstrate novel, highly oriented organic fibers for ballistic protective clothing materials. • Develop next generation advanced camouflage combat uniforms. • Develop reactive and catalytic protective clothing materials and uniform systems. • Integrate mission- and individual-tailored uniform system design and production capabilities for global rapid response and diverse missions. • OCRs supported: DBS 06, 09; EEL 08, 09; CSS 06, 07, 18, 20.
Sustainability	• Identify and optimize the incorporation of complex carbohydrates for modulated energy release during periods of high demand. • Develop a diesel fuel reformer capable of producing a natural-gas-like fuel for field kitchens. • Demonstrate wide span inflatable airbeam technology for the Aviation Maintenance Shelter. • Fabricate a 5-10K lb high glide airdrop system. • Develop glass-coating technology for flexible or semi-rigid retortable non-foil packaging materials to extend shelf life. • Develop in-package additives to prevent oxidation and other forms of product degradation. • Optimize properties of selected technologies to improve performance of reverse osmosis membranes for water purification. • Demonstrate innovative water purification technology for drinking water for field troops. • Demonstrate a parachute with a novel design that achieves a 20 percent reduction in weight, bulk, and manufacturing costs (compared with fielded parachutes) and provides equivalent flight performance. • Demonstrate a parachute retraction system using clustered parachutes that provides a less than 10 ft/sec soft landing capability. • OCRs supported: CSS 04, 17, 18, 20; EEL 02, 04, 16; MTD 03, 11, 18.	• Develop shelf-stable solid muscle foods providing A-like ration quality using irradiation. • Select/incorporate neurotransmitter precursors in ration components/supplements for anti-stress benefits. • Demonstrate a rapidly deployable field kitchen featuring advances in diesel combustion, heat transfer, integral power, and refrigeration that can produce high quality meals quickly and economically. • Validate nonthermal preservation techniques used to minimize nutritive losses. • Demonstrate interactive packaging technology (e.g., emitters/absorbers) for shelf-stable and perishable food production applications. • Demonstrate 5-10K lb high glide airdrop system and transition system to full-scale development. • Demonstrate a less than 10G (gravitational force) soft landing airbag system that provides an all weather, rapid roll-on/roll-off airdrop capablity for future Army. • OCRs supported: CSS 05, 18, 22; EEL 03, 05, 18; MBS 09, 13.	• Optimized calorie/nutrient consumption. • Targeted nutrient delivery systems to ensure maximum bioavailability of key nutrients. • Demonstrate a totally integrated, self-contained field feeding system based on advances in food, packaging, shelter and energy technologies. • Investigate powered gliding wing airdrop systems. • Demonstrate advanced recovery/ stabilization technologies that reduce ground dispersion and personnel/ equipment link-up times. • Demonstrate advanced airdrop performance simulation technologies, as virtual test proving ground enablers, that reduce test cycle time/cost. • OCRs supported: CSS 07, 17, 20; EEL 02, 04, 16; MTD 03.

G. Command, Control, and Communications

1. Scope

Command, control, and communications are key elements in the Army Modernization Plan to change the Army from an Industrial Age force to a Digitized Force XXI that is prepared to fight and win the information war. Command, Control, and Communications encompasses many interrelated technologies and specialties with emphasis in three major areas: decision making, information management and distribution, and seamless communications.

2. Rationale

Access to and exploitation of timely information is a key element of America's future warfighting and crisis management capabilities, as well as its national competitiveness. The projected force-level-multiplier advantage of information technology stands far above that of all other technical areas. Such capability, while greatly enhancing the autonomy and survivability of individual units, will quickly provide an advantage in any conflict, supporting early, decisive victory with minimal cost in assets and human life.

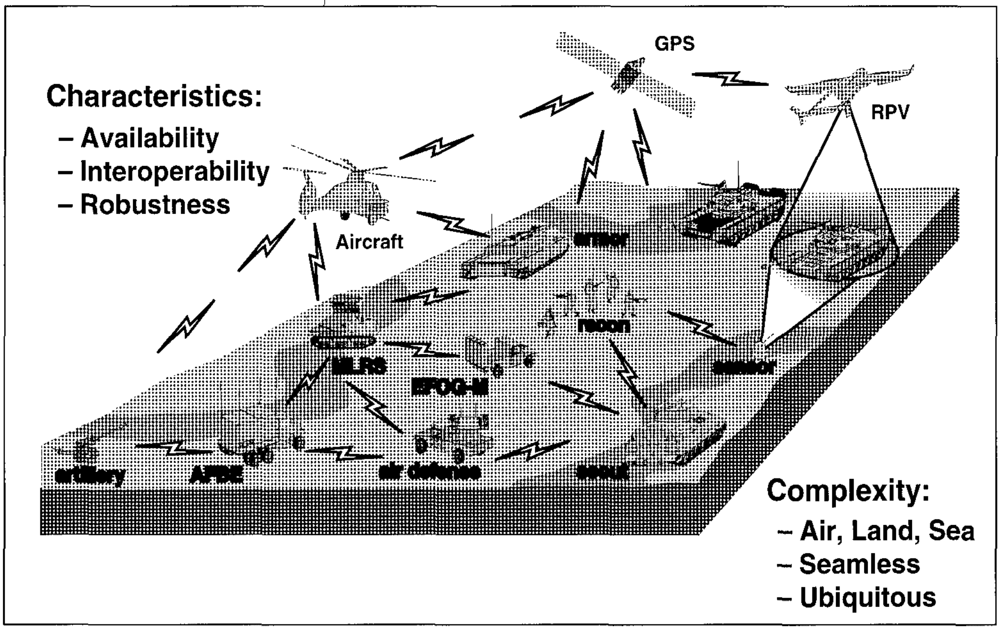
Decision Making is the heart of the command process and has the following areas of focus: Consistent Battlespace Understanding; Forecasting, Planning and Resource Allocation; and Integrated Force Management. It encompasses the development of common, modular elements that connect joint mission planning, rehearsal, execution monitoring, and common pictures of the battlespace.

Information Management and Distribution provides the information infrastructure and products needed for information security, distributed computing, distributed multimedia data bases, and visualization. This movement of information is critical to satisfying the warfighters' needs for the future.

Seamless Communications supports split-based operations by spanning the globe and interconnecting command echelons, Services, and allies worldwide through common transport protocols and dynamic network management. Emphasis is on mobility aspects of communication networks, network management, and heterogeneous transmission systems (e.g., wired and wireless). By focusing on wide bandwidth capabilities linked to our narrowband tactical systems, we can provide the correct critical information to the warrior anywhere in the world.

C3 programs will develop the technology to provide a real-time, fused, battlespace picture

Figure IV-G-1. Army Tactical Communications Environment



with integrated decision aids. The technology will provide the processing infrastructure, intelligent/anticipatory data manipulation and distribution, and dynamically adaptive broadband communications linkages required for both command and sensor-to-shooter applications. Warfighters will be able to exchange information unimpeded by differences in connectivity, processing, and interface characteristics. With these capabilities the Army will have the ability to establish distributed, virtual staffs that share a common, consistent perception of the battlespace.

Many of these advances in Information Science and Technology (IS&T) are being driven by commercial developments and products. The results can be brought to bear on Army problems through cooperative efforts and participation in efforts to set standards and establish policy. Costly Army-specific development will be avoided with the amortization of costs across government and commercial communities. However, there are aspects of command, control, and communications that must be strongly influenced or directly supported by the Army. In particular, developing the capability to reliably communicate to and among numerous, widely dispersed mobile sites operating in actively hostile environments; identifying friend and foe; achieving information security; and meeting the requirements for military-unique processing and decision support systems will not be achieved without significant Army support.

This technology area embodies enormous dual-use potential in numerous areas vital to economic competitiveness and other national concerns. Beside the direct application of this technology to defense sciences and engineering, it has great potential for other significant contributions: more effective health care procedures; enhanced education and lifelong learning; more timely and less costly procurement through electronic commerce; more efficiently managed and integrated transportation networks; delivery of innovative information services to average citizens; and sound methods of environment monitoring, weather prediction, and pollution control.

3. Technology Subareas

a. Decision Making

This subarea focuses on all elements of the decision making process, from tactical assessment through plan preparation, deconfliction, rehearsal, and execution. The major emphasis is on acquiring and assimilating information needed to dominate and neutralize adversary forces. A key capability is near-real-time awareness of the location and activity of friendly, adversary, and neutral forces throughout the battlefield area, providing a common awareness of the current situation. One of the primary objectives of information dominance is to meet the warfighters' needs for a flexible command structure that can be rapidly configured and dynamically adapted to optimize force effectiveness and survivability. The subarea applies leading-edge modeling and simulation (M&S) and computing and software technology to significantly improve warfighter performance by eliminating laborious, time-consuming manual procedures and processes that pervade U.S. operational planning and execution. Computer-aided processes and automation-synergistic procedures replace exclusively human processes and procedures. The warfighter is provided with an intuitive view of battlespace, an enlightened perspective of information (C2, intelligence, logistics, weather, and other critical data), and the ability to explore alternatives in faster-than-real time (e.g., exploring 10-hour battles in several minutes).

Goals and Time Frames

The goal is to provide automated, real-time decision support to the warfighter. The warfighter must rapidly interpret information received through interactive 2- and 3-dimensional presentation of the tactical situation (situational assessment cues identifying potential problems or interest areas). The Commander must view (from a situational assessment display) relevant forecasts for weather, enemy strength over time, friendly strength, logistics tail; conduct course of action analysis, allocate resources, wargame (real-time simulation) to explore battlespace options, and collaboratively plan and rehearse battles. Such a capability will result in the precise direction of a diverse, synchronized task force armed with overpowering information superiority and decision making capability.

Major Technical Challenges

The major challenges are to develop applications that employ intelligent agents for intelligent information retrieval, fusion, and presentation; fuse planning information with actual information in real time; provide real-time simulation (wargaming), planning, and rehearsal with sufficient fidelity on tactical platforms to influence battle outcomes; provide decision support in the presence of uncertain, incomplete, or absent information; develop applications for dynamic scheduling/coordination of assets for interdependent tasks; and provide collaboration tools that permit the spectrum of operations to be performed by remote, dispersed elements of a task force.

b. Information Management and Distribution

Information Management and Distribution encompasses warfighter needs and capabilities related to information warfare (IW) and information systems. IW and information systems include information, information-based processes, information systems, and computer-based systems either individually or in combination with each other. The key to providing this capability is a distributed information management and distribution system that forms the backbone information infrastructure of all future C4I systems. Providing technologies that allow automated, adaptive, and robust information resource management means we can free up the warfighter from the mundane and tedious tasks required to review and distribute information. By incorporating a context-based approach, information synchronization and management can be formally automated, allowing warriors (especially those at the fighting echelons) to concentrate on mission execution rather than on complex computer operations.

Goals and Time Frames

Required warfighter capabilities for Information Management and Distribution necessitate development in the constituent areas of Distributed Environments, Information Services Management, and Assured Information Services. These technology efforts will provide the warfighter with the ability to (1) access mission-critical data from any location on the globe in a location transparent manner, (2) collaborate on mission plans at all levels and monitor execution in real time, (3) assess mission plans through rehearsal using synthetic environments, (4) assure continuation of mission critical functions and survive loss of resources by dynamically reconfiguring where functions are executed and how information flows, (5) provide reachback from deployed forces to garrison and support units, (6) support interoperability among both joint and coalition forces, (7) support extension of the information backbone to highly mobile, deployed forces through the integration of mobile distributed computing nodes, and (8) maintain access control, authentication, integrity, and availability of classified data in a distributed information environment accessible by users with differing clearances and needs to know.

Major Technical Challenges

The critical challenges are areas associated with the infrastructure for the Distributed Environments, mechanisms to support Information Services Management which reside within the distributed environment, and the ability to deploy Assured Information Services. In the Distributed Environments infrastructure area the critical technical challenges are (1) distributed data storage and query, (2) scalability to several thousand nodes and schedulability of time-critical operations that are physically dispersed across large geographic areas, (3) varied user populations and applications, (4) multiple processor types, (5) capabilities and configurations, and (6) integration of both real-time and non-real-time operating environments within the same overall system. As always, compatibility with emerging commercial system standards and heterogeneous computing bases while retaining DoD's desired operational capabilities is vital.

Providing the necessary Information Services Management within the distributed environment requires the development of mechanisms for managing data both on individual hosts as well as across the distributed environment. The critical technical challenges to be met include (1) developing data models and storage and retrieval architectures capable of handling modalities of data in a seamless way, (2) merging and synchronizing time-dependent and non-time-dependent data, (3) developing intelligent agents capable of autonomously navigating complex data base structures and extracting information for a user, (4) developing natural language and other nonparametric interfaces to support "intuitive" access and retrieval of data from the data base management systems (DBMSs), (5) developing adaptive information distribution techniques based upon context based as opposed to message based distribution, (6) using the information context for smart distribution over low bandwidth communications in order to selectively control the quantity of information exchanged, (7) providing capability to respond to complete information exchange failures, and (8) scaling information distribution techniques to large systems of communications nodes.

The keys to developing Assured Information Services are (1) adaptivity within the distributed environment to allow dynamic response to varying loads of crisis management or system failure, and (2) protection of the information within the system from attack or compromise. The critical technical challenges include (1) security mechanisms for multi-clustered, real-time heterogeneous distributed environments; (2) adaptivity mechanisms which support the selective application of fault tolerance and fault avoidance strategies; (3) reconfiguration mechanisms to support graceful degradation; (4) replication mechanisms to ensure the consistency of information; (5) intelligent resource managers to dynamically respond to crisis overloads; and (6) system architectures that permit the secure use of COTS computers, software, and networks.

c. Seamless Communications

Seamless communications facilitates several of the warfighters needs for Information Dominance, Information Warfare, real-time Logistics Control, and Military Operations in Urban Terrain (MOUT). Communications is the mechanism to achieve secure, reliable, timely, survivable, command and control and superior battlefield knowledge. This subarea addresses technologies needed by the warfighter to obtain effective access to, and utilization of, global communications services. Seamless communications connotes assured, user-transparent, secure connectivity between globally dispersed sanctuary locations and positions in theater—down to the lowest echelon foot soldier or marine, and to each ship and aircraft. This connectivity will be accomplished using a combination of U.S. Government, foreign government, commercial infrastructures, and military surface-and space-based radio frequency (RF) networks. A range of transmission media, bandwidth, standards, and protocols will be accommodated automatically by the networks. Voice and all types of data (e.g., text, graphics, imagery, and video) will be handled within a uniform, information transport infrastructure. These technologies will provide the commander with high capacity, flexible, tactical communications to serve all categories of users (including mobile) and satisfy the need for high-confidence communications regardless of system limitations throughout all phases of the battle.

Goals and Time Frames

The goal is an affordable, survivable, self-managing, multilevel secure (MLS) communications system that provides the warfighter with user-transparent connectivity for voice and command, control, and intelligence (C2I) systems data over the entire combat/garrison operational continuum. The system must fully support wide- and narrow-band on-the-move (OTM) C2I data/voice interconnections throughout a land battle zone at least 100 kilometers (km) deep and provide robust and seamless connectivity between ground, air, and naval elements of the Coalition combat force dispersed over distances up to 200 km. Achieving this goal will require significant enhancement of tactical communications systems; development of automated, seamless interfaces between tactical systems and between tactical and global communications systems; development of sophisticated new radio and antenna systems for the airborne and ground OTM portion of the warfighting force; evolution of theater/global broadcast systems as an integral element of seamless communications; and development of artificial intelligence tools for network planning, engineering, management, and operations.

Major Technical Challenges

Major technical challenges in this area include (1) communications mobility/wireless mobility issues (both nodes and base stations); (2) communications equipment interoperability in multivendor, multinetwork, Joint/Combined force, and commercial environments; (3) infrastructure for wireless tactical ATM links; (4) protocols for high data-rate subscriber loops subject to sporadic disturbances (e.g., Narrowband ISDN [N-ISDN] and broadband

ISDN [B-ISDN] loops supporting OTM airborne/surface/subsurface vehicles; (5) construction of a fully Internet-compliant, tactical packet network using legacy radios such as Single-Channel Ground and Airborne Radio System (SINCGARS); (6) integration of data and voice over low bit-rate links; (7) heavy multipath and deep fade effects; (8) security; (9) development of network management and control protocols that can withstand the onset of federated and non-federated jamming attacks; (10) waveforms for low probability of interception (LPI) and low probability of detection (LPD); (11) development of conformal arrays for airborne and OTM antenna applications; and (12) Waveforms or software programmable radios.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Command, Control, and Communications is shown in Table IV-G-1, below.

Table IV-G-1. Technical Objectives for Command, Control, and Communications

Technology Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Seamless Communication	• Demonstrate broadband antenna for multi-band applications. • Demonstrate ground mobile ATM broadcast capabilities. • Develop and demonstrate IP-ATM hierarchical video reading. • Demonstrate user friendly, inexpensive security services. • Demonstrate tactical PCS capability based on commercial technology. • OCRs Supported: BC 06, 07, 09, 10, 17, 18, 20; CSS 02, 05; DSA 10, 20; DBS 15, 20, 21; MTD 17, 18; EEL 16.	• Demonstrate optical control of wide-band multipanel, phased array antennas for on-the-move applications. • Demonstrate antenna positioners for SHF/EHF SATCOM on-the-move applications. • Demonstrate next generation PCS technology for Land Warrior applications. • Demonstrate structurally embedded reconfigurable antenna technology in ground vehicles and airborne applications. • Demonstrate dynamic network survivability through protocol adaptation to external influences (weather, threat, congestion, etc.). • Provide virtual, integrated communications systems models for division/corps. • OCRs Supported: BC 06, 07, 09, 10, 17, 18, 20; CSS 02, 05; DSA 10, 20; DBS 15, 20, 21; MTD 17, 18; EEL 16.	• Demonstrate mobile seamless connectivity across communication media overcoming differences in connectivity, processing, and system interfaces (Universal Transaction Services). • Demonstrate/adapt future generation commercial PCS technology for tactical environments. • Demonstrate Automated Intrusion detection, Characterization response and damage restoral for tactical networks. • OCRs Supported: BC 06, 07, 09, 10, 17, 18, 20; CSS 02, 05; DSA 10, 20; DBS 15, 20, 21; MTD 17, 18; EEL 16.
Information Distribution & Management	• Distributed hetrogenous data base access. • Automated information distribution software. • Distributed computing over low bandwidth channels. • Machine-aided human translation of text for C2 interoperability. • OCRs Supported: BC 08, 11, 12, 14, 21; CSS 05, 24; DSA 07, 08; DBS 12, 13; MTD 14, 20; EEL 06, 12, 13.	• Access to multilevel secure distributed database. • Integrated, distributed semi-automated C2 at lower echelons. • Demonstration of seamless interoperable multilevel secure computing environment. • Fully automated translation (voice/text) in narrow domain C2 operations and enhanced natural language machine interfaces. • OCRs Supported: BC 08, 11, 12, 14, 21; CSS 05, 24; DSA 07, 08; DBS 12, 13; MTD 14, 20; EEL 06, 12, 13.	• Demonstrate extended relational and object-oriented DBMS system. • Scalable, transparent mobile computing environment. • Scalable secure distributed databases. • Natural Language interfaces for synchronized battle management. • OCRs Supported: BC 08, 11, 12, 14, 21; CSS 05, 24; DSA 07, 08; DBS 12, 13; MTD 14, 20; EEL 06, 12, 13.
Decision Making	• Terrain, environmental, and event detection decision support software. • Automated flight plan guidance algorithms. • Embedded software tools to enable real time collaborative planning in a 3D virtual environment. • Integrated and automated POS/NAV. • OCRs Supported: BC 02, 05, 13; CSS 02, 07, 28; DSA 16, 17; DBS 18, 19; MTD 19, 20, 27; EEL 19.	• Automated maintenance of consistent, timely tactical picture in distributed C3 system. • Automated situation assessment. • Demonstrate joint distributed collaborative planning and assessment tools with 3D visualization. • Automated cooperative interaction between three to four systems • Robust precision POS/NAV. • OCRs Supported: BC 02, 05, 13; CSS 02, 07, 28; DSA 16, 17; DBS 18, 19; MTD 19, 20, 27; EEL 19.	• Robust cooperation. • Software agents dynamically support collaborative planning and execution. • Dynamic immersive rehearsal planning and execution environment. • Autonomous navigation in well-characterized terrain. • Adaptive tactical navigation. • OCRs Supported: BC 02, 05, 13; CSS 02, 07, 28; DSA 16, 17; DBS 18, 19; MTD 19, 20, 27; EEL 19.

H. Computing and Software

1. Scope

The Computing and Software technology area is focused on supporting soldiers through development of novel computer hardware and integrated systems for Army applications. The Army's computing technology programs include (1) Scalable Parallel Systems and Applications; (2) High Performance Specialized Systems and Applications; (3) Networks and Mobile Computing; and (4) Wearable Computers. Software technology programs include (1) Software Engineering; (2) Data Engineering; (3) Artificial Intelligence; (4) Human Computer Interface; (5) Assured Computing; and (6) Distributed Interactive Computing. Information processing systems, computers, and communications, and the ability to rapidly adapt them to changing battlefield environments are an integral part of the technology edge to provide decisive victory in land combat.

The challenge is to identify efforts that preserve, extend, and leverage the Army's past, present, and future investments in software. The Army views integrated battlefield information systems and intelligent weapon systems as one of its most important sources of combat advantage into the next century. Yet, the software to support such integrated systems represents a challenge to conventional engineering, procurement, sustainment, and technology insertion practices.

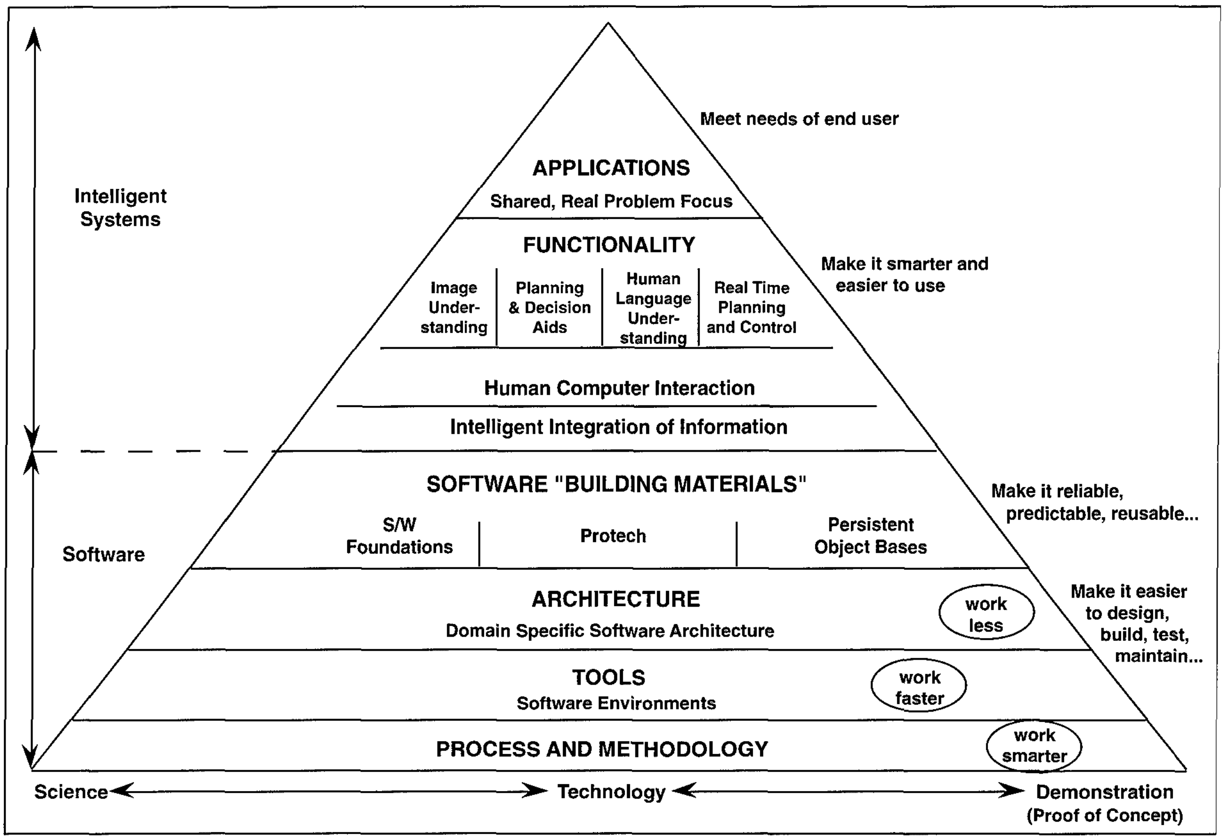
Software Technology encompasses a wide spectrum of highly technical specialties, activities, and processes including, but not limited to, the following: (1) Developing and producing algorithms and tools for the construction, operation, and life-cycle management of general application software and all of its associated artifacts; (2) All aspects of software engineering and life cycle management; (3) Software engineering processes and methodologies, tools, and frameworks (software environments) and Domain Specific Software Architectures (DSSAs) to make it easier to design, build, test, and maintain software; (4) Supplying the software "building materials" used to make software systems more reliable, uniform, predictable, and suitable for reengineering and reuse efforts; and (5) Information and data engineering that provide timely access to quality coordinated technical information. Software Technology at its foundation applies the general software engineering paradigms to "Work Smarter" (through process technology advancements), "Work Faster" (through advancements in tools and environments), and "Work Less" (through architectural and reuse technology advancements) to provide a technical environment for more intelligent and efficient application-specific engineering. Ultimately, Software Technology provides intelligent systems capable of integrating information, human-computer interactions, and general application software engineering functionalities to meet the real needs of the soldier on the battlefield (Figure IV-H-1).

2. Rationale

On the 21st century battlefield, the Army must rely on technologically superior systems to counter numerically larger forces, to reduce casualties and damage to urban infrastructure, and to enhance rapid, decisive action. Coupled with sophisticated applications software, high performance computing (HPC) systems and advanced communication technology enable (1) the design and optimization of "smarter," more cost-effective precision weapons; (2) rapid dissemination of battlefield information to tactical forces; (3) swift, global command and control based on accurate, comprehensive knowledge of the current situation which greatly enhances the autonomy and survivability of individual units; and (4) enhanced readiness and strategic planning capabilities through large-scale, distributed, authentic simulations. Research in this technology area encompasses computer and software engineering, operational simulation, battlefield environments, and science applications tools.

Many Army Science and Technology (S&T) problems require computational performance rates measured in trillions of floating point operations per second (teraflops or TFLOPS). These include problems in chemistry and materials science, computational fluid dynamics, parametric weight/vulnerability reduction, automatic target recognition, high performance weapons design, and dispersion of hazardous

Figure IV-H-1. DoD Software and Intelligent Systems Program



materials. Since no single HPC architecture will effectively handle this spectrum of problems, Army S&T researchers require a variety of computer systems which, in aggregate, support the highest fidelity and greatest speed in analyzing problems of ever increasing size and complexity. These diverse S&T applications also require massive, hierarchical data storage and scientific visualization capabilities to provide meaningful results. HPC utility will fundamentally drive or limit solutions to these critical problems.

The profound impact of modern, computer-driven technology has been amply demonstrated in recent hostile operations like Desert Storm and Joint Endeavor. Software is and will continue to be a force multiplier.

The Army is faced with a paradox. Systems are being extended in life and expected to achieve Land Force Dominance with diminished resources, in a changing world, with a reduced defense industrial base. Yet, the Army is expected to field lethal, versatile, and rapidly deployable systems in response to the requirement to win decisively and quickly on any battlefield and to do so with minimum casualties. [AMP 92—the Army Modernization Plan]

Computer resources in general and software resources in particular offer a solution to this paradox. The U.S. Defense strategy continues to be dominance based on superior technology. Changes in the world's geopolitics combined with current economic constraints have broadened the focus of attention on technology to include issues of flexibility and adaptability. In today's weapon system technology, software serves the role of providing these characteristics. Therefore, weapon systems will become more dependent on software to achieve these requirements. According to the Chief of Staff, Army, one of the most important lessons apparent from the Army's performance in Operation Desert Storm was the profound impact of modern, computer-driven technology on the outcome of battle. Desert Storm demonstrated the need to adapt and deploy the technology when and where it is needed.

The Army's challenge is that existing hardware/software systems are being extended and expected to achieve dominance through increased capability, while resources for that capability continue to shrink. Much of the evolving capability is provided by software. A change in hardware through product improvement has all the appearance of a new item, while a change in the software supporting that hardware is not viewed as a new item. This visibility mismatch furthers the gap between the perceived and actual costs of hardware and software sustainment. The goal of the Army software science and technology effort is to reduce software development and sustainment cost and schedules by an order of magnitude in the next 10 years.

An advantage of software is that it allows for short lead times and can be deployed over satellite communications links with essentially no logistics volume, weight, or fuel cost. However, software has usually been the critical path in product development. State-of-the-art training technology can provide expert systems that can train soldiers to use the new software on the battlefield. Changes to deployed systems can feasibly be made in theater through software modifications that have been previously tested in the Army's stateside Life Cycle Software Engineering Centers (LCSECs) where synthetic environments, interacting with real materiel, are used to demonstrate successful performance of the changed system.

With technology progressing at a rapid pace, the dilemma is that state-of-the-art software systems today become enormous cost burdens in the near future. Some systems deployed today and still in production require dated software maintenance and change techniques that are frozen in time and appear to be enormously expensive to sustain (e.g., interoperate, respond to threats). Yet, the cost to make these changes in hardware, to produce new hardware, to refurbish materiel, and to redeploy would be even more unacceptable.

The Army recognizes that research and development in software engineering, life cycle management, and environments are to a large extent commercially driven. Deployment of systems currently under development, and the employment of advanced concepts and operational scenarios that have a greater reliance on synthetic environments, will exacerbate the current dilemma faced in supporting deployed software. A paradigm shift is required in the way that software is viewed, supported, and developed. Increased reliance on commercial products will further increase costs unless the Army creates a win-win Defense-Industry scenario. The use of COTS software can produce significant benefits in reduced development and maintenance costs and improved product portability and maintenance; however, there are risks and issues associated with using COTS software. These include COTS applicability for real-time systems, life-cycle costs, modifications which may be required by Defense systems, and integration and performance issues which come into play when combining several COTS products into a single system.

The Army Software Technology Investment Strategy represents the distillation of extensive work performed by technical experts from industry, academia, and government software engineers and scientists to create such a scenario. The work plan is focused on the needs of the Army, windows of opportunity, and a realizable implementation given limited resources.

3. Technology Subareas

a. Scalable Parallel Systems and Applications

Goals and Time Frames

This subarea is concerned with development, exploitation, and deployment of high performance computers offering scalable performance for a broad range of Army and DoD applications. Scalable parallel systems technology includes parallel architectures, compilers, and programming tools essential to facilitate their effective use, systems software, mass storage, I/O, and visualization technologies. Applications requirements drive the design of these systems. Early access to new systems by DoD and Army users accelerates development of specific applications as well as knowledge, algorithms, and programming tools for solving problems. Current performance levels of 100 GFLOPS (gigaflops, or billions of floating point operations per second) will sustain a 10-fold increase by FY98 to reach the goal of 1 TFLOP.

The Army relies upon the DoD HPC modernization program to provide essential capabilities as described in the following DoD objectives:

- Increase the availability of the state-of-the-art HPC resources and supporting infrastructure for DoD R&D scientists, engineers, and analysts.
- Provide robust interconnectivity to these resources, the user community, and non-DoD collaborating scientists and engineers.
- Develop and adapt software tools and applications to fully exploit HPC capabilities.
- Actively engage other National HPC programs and leverage them to benefit Defense R&D.
- Focus national leading edge HPC research efforts in computing, high performance storage, software development, and networking to solve DoD S&T challenges.

Major Technical Challenges

Deployment of state-of-the-art HPCs provides an environment that allows the Army to solve critical mission problems and to tackle problems that are currently intractable. Improved HPC capability shortens design cycles by reducing the need to rely on handcrafted prototypes and destructive testing. Robust, high-speed connectivity is essential for daily collaboration with remote users.

Major issues are: (1) insertion of increasingly powerful processing nodes; (2) faster interprocessor communication; (3) global management of memory and data in cooperation with the operating system; (4) scalable I/O processing to match processor speeds; (5) software and applications development; and (6) the "learning curve" for Army users when programming in a massively parallel environment. DARPA has been a major national force in the development of scalable architectures and continues to be a dominant force in scalable computing.

b. High Performance Specialized Systems

Goals and Time Frames

The High Performance Specialized Systems subarea includes the development of innovative technologies such as optical processing, embedded systems, neural networks, and systolic processing that meet military requirements but have limited commercial potential. Target goals for these systems include a 200-fold increase in data reliability, a 10-fold system weight reduction, and a 5-time increase in digital data processing speed. The Army relies on DARPA and the other Services to provide technology for its systems applications.

Major Technical Challenges

The diverse deployment criteria for specialized Army systems makes hardening and repackaging essential. In addition, image and speech recognition dictates that DoD and the Services examine optical processing and neural computing. Incorporating fuzzy logic into neural networks for Army problems requires further research into expressing expert knowledge and combinatorial complexity in simple linguistic rules while reducing demands on computing resources.

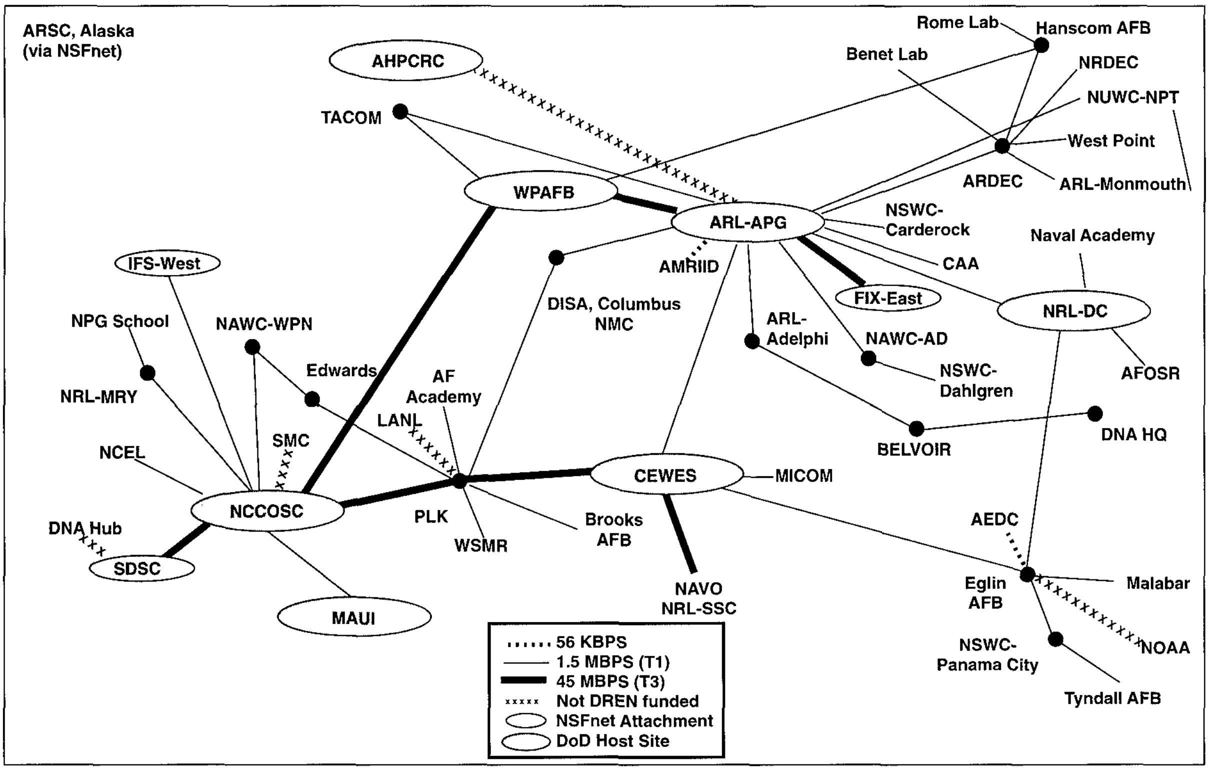
c. Networks and Mobile Computing

Goals and Time Frames

Winning the information war is a primary objective in the Army's modernization strategy. This requires integrated networking of battlefield and research-based computing systems. High speed and high capacity networks enable the interaction of research-based computing assets. Networking has long been the mechanism to foster scientific collaboration, and the Services were launched into this realm by the ARPANET initiative of the 1970s. This ARPA (now known as DARPA) program has grown to be integrally responsible for the Internet explosion which serves as the catalyst and foundation for the National Information Infrastructure project. Ten to 100 gigabit networking will be available by the year 2000.

As part of the DoD HPC Modernization Program, the Defense Research and Engineering Network (DREN) is being designed to maintain intersite communication performance levels commensurate with the I/O bandwidths of the HPC systems to which DREN will provide access (Figure IV-H-2). Bandwidth requirements are projected to approach 622 Mbps within 2 to 3 years, and over 1 Gbps (billion bits per second) within 5 years to support and enable distributed computing performance in the TFLOPS range. These requirements represent an order of magnitude (x10) increase over currently available bandwidth within one year and more than two orders of magnitude (x100) increase over current bandwidths within 5 years.

Figure IV-H-2. Interim DREN Configuration—1Q FY95



The Army has provided the technical lead in producing the interim DREN connectivity in anticipation of the award of the DREN component of the DoD HPC Modernization Program. Current Army mission projects in networking include, but are not limited to, the following: (1) Integrated Services Digital Network (ISDN) and Asynchronous Transfer mode (ATM) experiments over a NASA Advanced Communication Technology Satellite (ACTS) conducted in order to develop high bandwidth digital communications over widely separated LANs to allow widespread access to expensive resources (FY96); (2) wireless LAN testing of COTS high bandwidth equipment carried out to find the best suited wireless LAN for distributed simulation and communication for fast set-up/tear-down of military sites (FY96); (3) video, interactive graphics, and telecommunications over a desktop PC and fractal compression schemes allowing high data rate communications between distributed PC users, providing interactive voice, text, and graphics to a general PC user audience; and (4) executable protocol specifications using VHDL replacing ambiguous English language specifications with an unambiguous computer language specification to ensure that various COTS/GOTS telecommunications equipment will be interoperable (FY97).

Major Technical Challenges

The challenges include recognizing and identifying the most promising commercially available products and adapting these to Army needs. Since the environment and the conditions used in the commercial and military sectors are not synonymous, some adaptation may be required, especially in four areas: sensing, analysis, distribution, and assimilation. These factors turn combat information into knowledge, described by mathematical algorithms, and distribute the information in a hostile battlefield environment. The objective is to provide real-time, knowledge-based operations and seamless battlefield communications.

Technical issues being addressed include protocols for reliable, seamless connectivity as remote hosts increase in number and the exploration of high bandwidth data channels to offset the need for large-scale localized data storage. Security and data integrity issues are also of interest.

d. Wearable Computers

Wearable computers and their applications are starting to become feasible. They may act as intelligent assistants in many forms, from small wrist devices to head-mounted displays. They have the potential to provide anywhere, anytime information and communications. Possible applications include telemedicine (augmented reality), memory aids, maintenance assistance, distributed mobile computers in wireless networks (individual communication with soldiers on the battlefield), and desktop computing such as word processing, scheduling, and data bases.

e. Software Engineering

The Army Software Technology Investment Strategy (ASTIS) is a targeted strategy based on a principle that capitalizes on conditions of imperfect competition with our adversaries and rapid technological change. Stated in warfighter terms, "Hit them where we are strong and they are weak, with the technology transfer equivalent of overwhelming force." The ASTIS vision may be found in Figure IV-H-3.

Figure IV-H-3. Software Technology Investment Strategy Vision

- Minimize software cost and schedule drivers in DoD systems,
- Maximize the use of commercial best practice and products,
- Evolve systems and infrastructure, and
- Enable greater mission capability and interoperability to exceed expectations of the soldier in the field

This vision is realized through the establishment of a Virtual Advanced Software Technology Consortium (VASTC). Assets of a VASTC will be a distributed matrix of an integrated government, academic, and defense-industrial software and computer resource asset base.

The word "virtual" in VASTC emphasizes:

- An idealized machine—the technology transition engine, interconnected real assets that act like a technology center in one physical location; and one organization—the rich matrix of diverse collaborating entities that act as if they were one.
- The center of the future as an enormously flexible network, a virtual consortium yielding the illusion of an organization. The consortium can dynamically change out entities as required.
- Finally, the VASTC gets the right technology available to the right customer, virtually on demand.

A roadmap establishing, prototyping, demonstrating, and scaling up incremental capabilities hinging on this principle will yield an emphasis and paradigm shift. Each effort in the roadmap has the Strategy's building blocks of integrated, process, product teams, and the paradigm shift built in (see Figure IV-H-4). The result will constitute the creation of a distinct techno-economic paradigm built around flexibility rather than simple volume production and relying on a commercial infrastructure versus a dedicated defense-industrial complex.

The ASTIS guides the industrial structure toward key critical technology sectors. These sectors include computers and software support for the development of capital goods such as

Figure IV-H-4. Software Technology Investment Strategy

The Strategy consists of three components and an integrating concept. These are:

- Process - transition technology for affordability.
  - Focus emerging software process technology
  - Integrate discrete technologies
  - Mature the Army's supporting infrastructure
- Product - Domain/Product Line Management and Horizontal Technology Integration
  - Evolve common components
  - Converge to Domain specific architectures
  - Pre-Planned Product Improvement (P3I) of legacy software
  - Establish software exit criteria for Advanced Technology Demonstrators
- People - Professional development of the matrix
  - Government
  - Industry
  - Academia
- Paradigm - Integrating Concept -- Virtual Advanced Software Technology Consortium (VASTC)
  - Focused expertise and technology
  - Prototype software technology incubators
  - Integrated distributed incubators
  - Life Cycle Software Engineering Center of the Future

aircraft, ground transportation vehicles and systems, and flexible manufacturing facilities as well as telecommunication and battlefield information systems. These are the sectors having the greatest growth and technological potential.

Virtual Advanced Software Technology Consortium (VASTC)

Goals and Time Frames

The VASTC offers industry and academia distributed yet integrated advanced technology transfer incubation facilities where the emerging technology comes together to enable risk-reducing "proof of principle" demonstrations conducted with access to materiel in an operational environment, evolving synthetic environments, a distributed high performance computing infrastructure, and advanced large-scale program management techniques. The VASTC establishes a rapid software technology transition channel for the Army and the Nation.

Figure IV-H-5 is a graphical depiction of a single software technology incubation cell. The VASTC incubators scale up immature, emerging, and mature technologies and integrate these technologies into existing environments. Real systems are the test articles and have the beneficial side effect of reducing risk on the actual programs. Deployed (in service engineering), new developments, and advanced concept systems provide scale-up opportunities and real world challenge problems. Yet, the artifacts from the incubators are reusable components that are targeted to domain-specific software architectures.

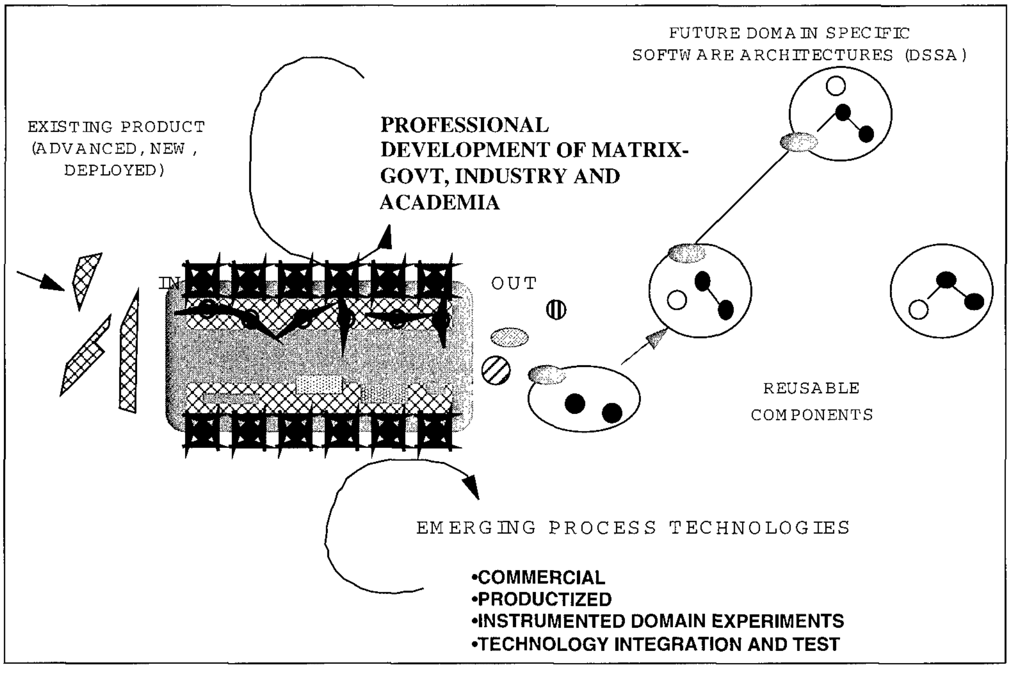
The VASTC offers the government an engine to continuously reduce risk and insert technology into existing weapon system software. The VASTC is also a software technology training factory. People are educated and trained on the use of the new technologies, while analyzing and modernizing existing systems. The software training factory operates on existing systems with new technologies. The VASTC training factory will optimize resources and reduce risk by acting as a booster to future builds of existing systems.

Regardless of a VASTC participant's role (e.g., academic, principal investigator, IR&D exploration, governmental staff development, or retreading), the technology will flow with the participants. The VASTC will be a national asset and an engine of technology transfer, influencing commercial practice and government products.

Major Technical Challenges

Key to realizing the vision of the VASTC will be the capability to provide integrated automation capabilities throughout the software life cycle. Process automation is a relatively new area of

Figure IV-H-5. Software Technology Incubator Concept



research with many technical challenges. A common underlying infrastructure for each of the individual technologies being automated that allows ease of integration and supports evolutionary development will be necessary. Early efforts will be directed at developing this underlying infrastructure and providing an open interface that encourages tool vendors to build tools that support VASTC.

Next Generation Life Cycle Software Engineering Center

Goals and Time Frames

The amount of Army software (old, modified, new) requiring life cycle software engineering services is increasing exponentially along with life cycle costs. To address this issue and bring costs under control, the Army has initiated a conceptual shift in how future life cycle engineering services will be accomplished. At the core of this initiative is the Next Generation Life Cycle Software Engineering Center Prototype. The goal of this new center is to reduce weapon system software development and support costs by at least an order of magnitude. The goal will be achieved by creating a seamless software engineering directorate within the Army Materiel Command (AMC) that shares resources, knowledge, and best practices among its members with a focus on the customer. The concept is being prototyped at the Tank Automotive and Armaments Command (TACOM) and scaled to an AMC-wide infrastructure capable of supporting FORCE XXI.

Major Technical Challenges

New networking tools and architectures must be sought out to fully achieve interoperability between geographically dispersed member organizations. Also new management processes will be needed that can adapt to the many different systems supported by member organizations and their organizational cultures. Additionally, current software development and maintenance methods will need to be integrated into a seamless activity capable of being performed throughout this virtual center.

Requirements Validation

Goals and Time Frames

Embedded software packages, like software for aircraft control, are critical in the sense that if they fail, soldiers die. A study is ongoing to determine how rapid prototyping technology and graphic visualization of software can be used to validate the air worthiness of flight control software. If feasible, in FY97, a prototype version of a requirements validation tool will be developed to be incorporated into the Aviation and Missile Command (AMCOM) LCSEC and the Next Generation Life Cycle Software Engineering Center.

Major Technical Challenges

Since air worthiness depends not only on the reaction of integrated hardware and software to stimuli inflight but also on human reaction to the stimuli, accurate models of this human reaction must be developed.

Computer-Aided Prototyping

Goals and Time Frames

Computer-aided prototyping is an evolutionary software development paradigm that involves the end user of the software in the requirements development process. This paradigm makes use of prototype demonstrations and user feedback to iteratively develop a functional prototype. Prototypes are executable specifications of software systems partially generated and partially built from atomic components retrieved from a reuse repository. Current efforts are directed at maturing and commercializing this technology to enable practical use by the Life Cycle Software Engineering Centers in the RDECs to include the NGLCSEC. Our goal in FY97 is to investigate the incorporation of groupware technology into our rapid prototyping testbed to realize a collaborative software development capability.

Major Technical Challenges

Groupware tools for electronic meetings and information sharing are insufficient to handle the vast amounts of data and interaction necessary to provide a practical collaborative capability. New paradigms for interactive development that incorporate not only real-time interaction, but also delayed time interaction are necessary to realize this vision. Additionally, tools which provide for the formal verification of requirements developed using group tools must be sought to make this a viable goal.

System Evolution Record

Goals and Time Frames

Future system development will require vast amounts of data to be collected and made available throughout a system's life cycle. A System Evolution Record (SER) is needed to serve as a "cradle-to-grave" repository for all artifacts and decisions made during the evolution of a software system. An initial model of a SER is being prototyped. Our goal for the next and subsequent years is to implement the SER and begin to model different pieces of the software development process to integrate with the SER.

Major Technical Challenges

New techniques for capturing design decisions must be developed to allow for the linking of these design decisions into the SER. Hypergraphs must also be developed that will store not only the artifacts to be contained in the SER and the decisions already mentioned, but also dependencies between them.

f. Artificial Intelligence

Goals and Time Frames

Exploiting emerging high performance computing, storage and retrieval, and communications systems for the Army's electronic battlefield (EBF) requires advanced software capabilities incorporating artificial intelligence (AI). After 2000, Distributed Interactive Simulation (DIS) software capabilities are expected to include cooperating intelligent systems, coupling of symbolic and neural processing, and autonomous synthetic agents and robots. The result will be a large synthetic computing environment in which networking and process management are handled automatically and are transparent to the users. Features will include multilevel secure data routing, loci of computation, workload partitioning, and interconnection of government and industry/academia expert and information centers with built-in ownership protection. By 2010, planning systems capable of complete support of military operations and deployment with less than 24 hours notice will become available.

The Army Federated Labs Broad Agency Announcement will focus basic research in five areas, each of which will need Artificial Intelligence Technologies. These areas are Advanced Sensors, Advanced and Interactive Displays, Software and Intelligent Systems, Telecommunications and Data Distribution, and Distributed Interactive Simulations. Three approved consortia will work on Army-specific basic research over the next 5 to 8 years. The Army Artificial Intelligence Center manages the Army Artificial Intelligence Program, which is focused on applied research and prototyping to deliver artificial intelligence solutions in support of Force XXI. A number of expert systems have been delivered, and emerging technologies such as fuzzy logic, neural networks, and genetic algorithms are being used to build advanced technologies.

Major Technical Challenges

The study of Artificial Intelligence has produced advanced technologies that can be placed in three categories: Mature, Emerging, and Immature. Expert and rule-based systems are examples of mature technologies that are being widely used in commercial applications. The major challenge is to develop prototypes for Force XXI and identify appropriate technology insertion in existing systems and systems under development. Fuzzy logic, genetic algorithms, and neural networks are examples of emerging technologies. The development of prototypes for exploratory development and risk mitigation will clarify the technical issues. Finally, intelligent agents and machine learning are examples of immature technologies. These are the focus of the basic research efforts in the Army Federated Labs.

g. Human-Computer Interface

Goals and Time Frames

Human-computer interactions deal with the systematic application of scientific knowledge about humans to design the simulated human and its behavior as well as the interface software through which real humans interact with the synthetic environment. The Army programs addressing the physical human-machine interface and the human engineering aspects are described in Section N, *Human Systems Interface*. Information display and human-computer communications technologies are steadily advancing. COTS user interface management tools, standards-based approaches for product development, style guides, graphical information visualization, etc., are now available for commercial and military applications. The Army programs addressing human-computer interactions rely on these general tools to make computers and associated networks easier to use as well as to build. This is a continuous process.

Major Technical Challenges

An important aspect is the adaptation and interface of the large number of previously developed application-specific closed architecture codes with the COTS human-computer interaction tools. Connected speech systems with increasing natural language interpretation and voice recognition that can be trained quickly for different voices are appearing, but they lack robustness for military applications. Group system capabilities are needed to provide for multi-user interfaces in to software systems.

h. Assured Computing

Goals and Time Frames

Assured computing and high assurance software are concepts which provide compelling evidence that the computer system/software will respond correctly under all required circumstances with respect to specific high assurance criteria such as security, safety, or timeliness. The system should provide a high level of assurance that it can enforce a specific security policy relating to, for example, confidentiality, integrity, or access. It ensures it will not enter a hazardous state. Other properties which may require high assurance include integrity, availability, and fault tolerance. High assurance is required for software that implements critical requirements. These requirements are implemented by system characteristics, or properties, whose absence or minimal existence may cause serious errors in the operation of a system. Critical requirements may exist in abstractions at all levels—from the end user environment interface down through various computer subsystems and operating systems to the computer hardware. A critical requirement at a high level of abstraction would be human safety. Low abstraction level requirements include guaranteed timely performance, freedom from deadlock, and unacceptable degradation, automatic fault recovery or fault masking, and controlled access to secure data.

Major Technical Challenges

Safeguarding of information, loss-of-service protection, and damage prevention to programs and data through errors or malicious actions requires multi-level security, defense against malicious software, and credible procedures for technical evaluation, certification, and accreditation of software. Speed of access to data, in a tactical missile system, for example, can determine success or failure. Authentication, access control, and audit together provide the foundation for information and system security. A number of technical issues arise in the form of data base tuning mechanisms, access methods and control, query optimization, concurrency control, and replication and reliability protocols. Defensive Information Warfare provides secure, possibly COTS-based, computing clusters, data bases, and tools to support high assurance computing. DoD is currently implementing Defense Technology Objectives (DTOs). These DTOs are planning objectives for achieving specific functional and operational capabilities as elements of Joint Warfighting Capability Objectives (JWCOs). Three DTOs that specifically address high assurance computing are Survivable Information Systems, Defensive Information Warfare, and Assured Communications. Currently 12 JWCOs are defined in the Joint Warfighting Science and Technology Plan (dated May 1996). The Army has relied on NSA to provide the required assured computing technologies.

I. Distributed Interactive Computing

Goals and Time Frames

Instant access to information on computer systems throughout the world is now a reality. "Surfing the web" has become a national pastime for internet users in and out of the government. The World Wide Web (WWW) provides the capability for anyone with access to the internet to access information on every imaginable subject at any time of the day or night, and on any machine that contains a WWW server. This technology is being exploited in many ways to increase information sharing between agencies and to further our movement toward a "paperless" Army. WWW servers have been established at virtually every organization that provides information or services to the Army. Publications and forms have been made available electronically and policies should encourage the use of electronic forms and publications. Applications are now available that can be accessed completely through the web, making every web server available to almost any user.

This is a relatively new area of investigation, and definitive near-, mid-, and far-term goals are still in the early stages of formulation. The tremendous rate of growth in WWW technologies offers the promise of many significant advances within a very short timeframe. Army planning will, in part, be driven by the rapid changes in available marketplace technologies.

Major Technical Challenges

The most critical challenge in this area is the ability to provide secure access to sensitive information, allowing easy access to authorized users while preventing unauthorized access. This technology is moving faster than even industry can keep up with. Most of the development of WWW applications is being done by "hackers" working nights and weekends with no wish for compensation. Capabilities for increased information availability and increased interactivity have resulted in our inability to control what information flows and where. Future research must design ways to protect critical information while providing access to necessary information and capability.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Computing and Software is shown in Table IV-H-1. The Army software program is structured to take advantage of emerging commercial software technologies and relies on the DoD software program for most of the generic software technology, including tools and techniques for software engineering, reuse, and life-cycle management. This program is integrated into the Tri-Service Reliance and addresses only those technology areas where DoD program investment will not satisfy Army-specific application needs.

Table IV-H-1. Technical Objectives for Computing and Software

Technical Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
High Performance Computing and Scalable Parallel Systems	• Shared DoD HPC infrastructure. • 100 gigaflops performance. • Gigabyte RAM with microsec access. • OCRs supported: BC 03.	• Scalable HPC and distributed heterogeneous sysTems transitioned to the EBF • Teraflops systems for S&T arena.	• Petaflops systems in S&T labs. • EBF at 100 teraflops.
Networking	• DREN and gigabit networking. • High bandwidth interconnected COTS/digital communications over GOTS telecom equipment; separated LANs. • Wireless LAN testing. • OCRs supported: BC 01, 06, 09; DSA 10, 15; DBS 20; MTD 17.	• 10 to 100 gigabit networking.	• Ultrafast, all optical WANs.
Software Engineering	• Initial Software Reuse through rudimentary stand-alone repositories. • Massively parallel Ada • Computer-Aided Rapid Prototyping • System Evolution Record for Reengineered Systems. • Virtual Life-Cycle. • Center implementation. • OCRs supported: BC 01, 02; CSS 18; DSA 16.	• Full Scale Reuse through domain specific software architectures and evolvable legacy systems. • Fully integrated Virtual Advanced software technology Consortium	• Software commerce on demand. • Integrated capability to develop, field, evolve, and maintain software through VASTC.
Artificial Intelligence	• Widespread use of AI mature technologies in battlefield systems. • OCRs supported: BC 03; DSA 09, 16; MTD 17, 20; TRD 03.	• Cooperating intelligent systems and symbolic/ neural processing included in DIS software capabilities.	• Intelligent planning systems capable of complete support of military operations and deployment 24 hours a day.
Human Computer Interface	• Graphical open interfaces for all new software systems fielded.	• Single-user voice recognition interfaces for limited software systems fielded.	• Multi-user voice recognition interfaces for all Army software capable of filtering out noise interference.
Assured Computing	• Risk modeling. • Security properties modeling. • Information Warfare (IW) paradigms.	• Formal specification languages. • Trusted systems. • Evaluation criteria for network security properties. • AI-based intrusion detection. • Certification of reusable components.	• Formal reasoning systems. • High assurance software models. • Certification methodology and tools for critical properties.
Distributed Interactive Computing	• Heterogeneous distributed operating systems service (limited capability). • Distributed data base services over homogeneous data bases. • T1, T3 available.	• Distributed OS services (enhanced capability). • SOL for multimedia data base queries. • Macro-building capability. • Scalable application components.	• Dynamic reconfiguration for R-T systems. • Multiple data base, multimedia query capability optimized. • Interoperable heterogeneous algorithms. • Automated adaptive load balancing.

I. Conventional Weapons

1. Scope

The ultimate goal of all weapons systems is to destroy the target. The Conventional Weapons Technology area develops conventional armaments for all new and upgraded non-nuclear weapons. It includes efforts directed specifically toward non-nuclear munitions, their components, and launching systems, guns, rockets and guided missiles, projectiles, special warfare munitions, mortars, mines, countermine systems, and their associated combat control. There are six major subareas: (1) Fuzing—Safe and Arm, (2) Guidance and Control, (3) Guns, (4) Mines/Countermines, (5) Warheads/Explosives and Rocket/Missile Propulsion, and (6) Weapon Lethality/Vulnerability.

2. Rationale

The Conventional Weapons Technology Area strongly supports the needs of the Army in both tactical and strategic mission areas. It responds to the Army's operational needs for cost-effective system upgrades and next generation systems in support of the top five Joint Staff future warfighting capabilities. Performance objectives focus on projecting lethal or less than lethal force precisely against an enemy with minimal friendly casualties and collateral damage. Objectives address the need for affordable all-weather, day-night precision strike against critical mobile and fixed targets; all-weather defense against aircraft, ballistic missiles, and very-low-observable cruise missiles; an effective mine detection and neutralization capability to permit movement of forces on land; more lethal/lighter weight gun/missile systems to support current and advanced air/land combat vehicles; vehicle self-defense systems; and lightweight, high-performance gun systems for artillery applications.

Conventional weapons technologies, when developed and demonstrated, have both an excellent historical record of transition and many future transition opportunities. Examples of the latter include systems currently under development [Javelin, Line-of-Sight Anti-Tank (LOSAT), Enhanced Fiber-Optic Guided Missile (EFOGM)]; potential upgrades to existing systems (Patriot fuze); and potential new systems [Intelligent Mine Field (IMF), Crusader, Precision Guided Mortar Munition (PGMM), Autonomous Intelligent Submunition (AIS), 155mm Automated Howitzer (AH), Extended Range Artillery (ERA) Projectile, and Low Collateral Damage/Less than Lethal (LCD/LTL) munitions].

Dual-use applications include use of fuze technology to provide aircraft precision altimeters, accelerometers for automobile airbag release, and automobile collision avoidance sensors; countermine technology to provide de-mining in affected areas; guidance and control technology to provide real-time medical imaging; new explosives for oil well drilling; and nonlethal technologies for law enforcement.

3. Technology Subareas

a. Fuzing—Safe and Arm

Goals and Time Frames

Fuzing—Safe & Arm technologies address issues associated with advanced future threats, both air and surface. Primary emphasis is on advanced sensors, signal processing algorithms, guidance integrated fuzing, Global Positioning System (GPS), miniaturized solid-state components, countermeasure resistance, electronic safe and arm, reliability, and affordability. Major products include a second launch environment sensor demonstration in FY96; laboratory prototypes of long stand-off fuzing for Active Protection Systems (APS) defeat in FY97; a Guidance Integrated Fuze (GIF) demo in FY97; an ECM/EMI resistant All-up Round Fuze demonstration in FY98; and algorithms to direct and fuze aimable warheads in FY99.

Major Technical Challenges

The primary technical challenges for guidance integrated fuzing are in the areas of simulation and modeling, sensor and signal processing, target characterization, and testing. The challenge for gun munitions is to develop affordable fuzes that will function at the desired point in an adverse environment [electronic countermeasures/electromagnetic interference (ECM/EMI), obscured targets, cluttered battlefield].

Specific challenges:

- Construct a GIF simulation to provide a common basis for comparing performance of different concepts under given sets of flight dynamics.
- Miniaturize GPS components.
- Integrate RF and IR hardware/software to operate in both guidance and fuze time domains spanning three orders of magnitude (10-3 to 10-6 sec).
- Sense a second launch environment for safing and arming non-spin munitions.
- Devise a small generic electronic safe and arm fuze with dual safeties for tank and mortar applications.
- Solve the helicopter-in-clutter problem by developing an electrostatic sensor fuze.

b. Guidance and Control

Goals and Time Frames

Guidance and Control (G&C) of conventional weapons is the application of sensors, computational capability, and specific force generation that allows a weapon to engage both fixed and moving targets with improved accuracy and lethality while minimizing collateral damage and casualties. The major milestones are as follows: By FY97, complete the evaluation of data compression methods that minimize error rates on an automatic target recognizer (ATR). By FY98, demonstrate performance gains in ATR from multispectral sensor identification of aircraft utilizing high range resolution radar profiles, electronic support measures, and jet engine modulation. By FY98, complete hardware-in-the-loop evaluation of prototype guidance sections of 2.75-inch precision guided rockets. By FY98, demonstrate, through simulation and both sled and flight testing, a man-in-the-loop fiber-optic guided missile system with a 40 km range. By FY99, demonstrate a low-cost, ultraminiature, manufacturable fiber-optic gyro. By FY00, demonstrate a strapdown laser seeker for a precision guided 2.75-inch rocket.

Specific challenges:

- Transfer ATR technology into systems.
- Integrate microelectromechanical systems technology into the thrust on precision guidance of small diameter weapons.
- Achieve navigational grade performance with ultraminiature fiber-optic gyros.
- Achieve innovative strapdown designs for laser infrared and multispectral seekers.
- Validate static and dynamic target models for combat identification of aircraft.

Major Technical Challenges

G&C technologies, involving guidance information and signal processing, inertial sensors and control systems, and missile system sensors and seekers, present three major technical challenges: precision guidance of small diameter weapons, enhanced target acquisition including masked target detection, and operational performance measures for multispectral missile seekers. Responding to these challenges will require the infusion of a number of emerging technologies that are not currently in the G&C program. The G&C program is coordinated with the technical objectives in the Manufacturing Technology program to achieve manufacturing and producibility goals and extensive use of simulation is made to reduce overall R&D costs.

c. Guns—Conventional and Electric

Goals and Time Frames

The Guns subarea develops both conventional and electric gun technologies for all new and upgraded gun systems (small arms, mortars, air/surface combat vehicles, tanks, and artillery). It includes efforts directed toward future, advanced, generic technologies and system technologies for small, medium, and large calibers, including barrel/launcher, ammunition/projectile, power supply and conditioning, weapon mechanism/ammunition feeder, propellants/ignition systems, and fire control. Products include the Objective Crew-Served Combat Weapon demo in FY97; low collateral damage/less-than-lethal munition demo in FY97; a demo for a large footprint munition and sensor concept (Damocles) in FY97; the LAH demo in FY98; and the Precision Guided Mortar Munition demo in FY99.

Major Technical Challenges

Major challenges include improving hit probability and lethality on target, extending the maximum range, reducing the weight of the total system, all-weather operation, and reduced barrel wear. Advances in composites, new propellant initiatives, and sophisticated electronics hold promise of overcoming many of these challenges.

Specific challenges:

- Use composite materials to reduce the weight of individual and crew-served weapons.
- Integrate fuze control for precision air burst on individual and crew-served weapons.
- Enhance ballistic aspects of tungsten materials to provide penetration performance goals with less environmental impact than DU material.
- Exploit composites to fashion a cargo-carrying artillery round capable of delivering twice the payload of metal projectiles at current ranges.
- Demonstrate new lethal mechanisms to defeat explosive reactive armor.
- Develop an ETC tank gun with 18 MJ muzzle energy and 1.9 km/sec muzzle velocity.
- Develop tactical size advanced pulse power supplies capable of supporting large caliber ETC and electromagnetic tank guns.
- Demonstrate new propellant architectures and formulations which improve muzzle velocity by at least 25 percent.

d. Mines and Countermine

Goals and Time Frames

The Mines/Countermine subarea includes all efforts pertaining to the development or improvement of land mines, and all efforts pertaining to detecting, marking, breaching, neutralizing, or clearing land mines. The major products include the Intelligent Mine Field (IMF) demonstrating long-range detection/tracking and autonomous, intelligent attack of mobile targets by FY98; a two- to four-fold improvement in individual mine detection for anti-personnel mines and neutralization capability by FY99; a portable, stand-off detector and neutralizer for buried antitank and anti-personnel non-metallic mines at maneuver speeds in FY00; and demonstration of high-speed reconnaissance and breaching of minefields in FY05.

Major Technical Challenges

Major technical challenges include the ability of acoustic sensors to accurately identify and track targets, the maturation of sensor fusion algorithms, and the implementation of tactical response algorithms. Mine detection, neutralization, and minefield breaching have challenges: rapid detection of mines (most false alarms eliminated) and the requirement for 100 percent assurance of removal, destruction, or neutralization.

Specific challenges:

- Increase probability of detection during all weather conditions.
- Extend the mine's sensor range by a factor of four.
- Combine detection and neutralization capabilities.
- Enable robotic (autonomous and semi-autonomous) mine neutralization and extraction.
- Reduce false alarm rate.

e. Warheads/Explosives and Rocket/Missile Propulsion

Goals and Time Frames

The Warheads/Explosives and Rocket/Missile Propulsion subarea develops conventional warheads, explosives, and rocket/missile propellants for anti-air, anti-surface warfare. It includes efforts directed specifically toward advanced non-nuclear warhead concepts, advanced kill mechanisms employing multi-option warheads, new warhead materials, material process techniques, analytical design tools, advanced explosives, and adaptable, minimum smoke, insensitive propellants for rockets and missiles. Products include a demo for a focused reactive frag warhead in FY98; a FY00 demo of liquid propellants to combine the specific impulse and energy management of liquids with the field handling simplicity of solids; demonstration of more energetic explosive formulations; and a 90 percent reduction in the emissions from explosive processing and demilitarization by FY05.

Major Technical Challenges

The major challenge is to provide affordable performance optimized and matched to a broad range of targets and intercept conditions, while maintaining or reducing the weight and size of the warhead/rocket. Promising new materials, such as tantalum, molybdenum, and tungsten, may provide dramatic improvements in warhead lethality. The challenge is to understand the relationship between microstructure and plastic flow of tantalum, upset forging optimization of tungsten, and parametric process variations in molybdenum/tungsten alloys. Higher performance requires more compact, higher energy density insensitive explosive formulations.

Specific challenges:

- Design a warhead that produces multiple compact/controllable pattern fragments using detonation wave dynamic models, which predict fragment geometry, size, and velocity.
- Improve penetration of very short/long stand-off shape charge and explosively formed warheads.
- Desensitize explosives by recrystallization to eliminate defects, by coating particles to reduce friction, or by reformulation.
- Synthesize new explosive and propellant formulations using composites of new, less sensitive energetic constituents, which produce environmentally "clean" exhaust products.
- Design fuel-efficient, lightweight, low cost turbine engines and inducted/air-augmented rockets.

f. Weapon Lethality/Vulnerability

Goals and Time Frames

Weapon Lethality/Vulnerability (L/V) refers to the science of understanding the mechanisms by which a warhead or other ballistic mechanism can defeat a target. Vulnerability, a characteristic of a target, describes the effects of various damage mechanisms to the physical components of the target and the resulting dysfunction. Lethality, normally used from the perspective of the attacking weapon, includes the ability of the weapon to inflict the damage mechanisms upon the target, as well as the effects of those mechanisms (target vulnerability). The L/V subarea addresses the tools, methods, data bases, and supporting technologies (e.g., solid geometric modeling tools, modern coding environments, supportive hardware configurations) needed to assess the lethality and vulnerability of all U.S. weapon systems including aspects of design, effectiveness, and survivability. Products include incorporation of tri-Service fragmentation and blast models in FY97 and FY99, respectively; and a 10-fold decrease in software preparation time in FY05.

Major Technical Challenges

The biggest challenge is to begin the complex task at the earliest possible stage in the weapon development or upgrade cycle, where inexpensive changes can lead to large increases in the survivability of crew and materiel and enhanced battlefield performance. To complicate matters, new penetrators (e.g., hypervelocity missiles, top attack systems, tactical ballistic missiles) must be modeled against an increasing list of sophisticated targets with new materials and novel armor designs.

Specific challenges:

- Develop first generation models to predict terminal effects on composite materials.
- Use statistical prediction methods to characterize fragment/debris clouds behind armors accounting for all fragment parameters (e.g., mass, speed, shape, spatial distribution).
- Extrapolate current L/V data to predict effects in new encounters with different materials and systems.
- Determine sensitivity of modern electrical subsystems and other components to ballistic blast and shock.
- Predict synergistic effects of concurrent damage mechanisms (fragment/penetrator and blast/shock) on structural components.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Conventional Weapons is shown in Table IV-I-1, below.

Table IV-I-1. Technical Objectives for Conventional Weapons

Technology Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Fuzing—Safe and Arm	• Incorporate neural nets, advanced sensors, and high speed processors in GIF to increase system effectiveness by 30%. • Collect target signatures for electrostatic sensors (ESS). • OCRs supported: DSA 01; DBS 02A; MTD 01.	• Flight test electrostatic sensor to establish jam immunity. • Demo fuzes with a 100-fold increased ability to resist projected ECM/EMI threats. • OCRs supported: DSA 02; DBS 05A; MTD 02.	• Provide airburst functionality to cannon-caliber munitions. • Improve logistics by developing universal fuze components and subsystems. • OCRs supported: DSA 03; MTD 05.
Guidance and Control	• Utilize ATR and neural networks in aimpoint selection algorithms. • Flight test IR seeker that acquires the target in flight. • Demo autonomous ground target acquisition algorithms and processors that use multiple spectral bands and data fusion. • OCRs supported: DSA 01, 02; DBS 05A; MTD 01; EEL 02.	• Demo aimpoint selection via neural net. • Demo strapdown MMW seeker that can acquire and track in a real-time lab test. • Develop solid-state/ photonic components that reduce the cost of G&C systems by a factor of 3. • OCRs supported: DSA 03, 09; DBS 13; MTD 02, MTD 03; EEL 06.	• Automate G&C software generation reducing acquisition cost by >10%. • Exploit multisensor target/scene simulation to reduce test and evaluation costs by 30%. • Develop advanced hardware/software codesign techniques. • OCRs supported: DSA 12, 13, 14; DBS 14; MTD 05, 22; EEL 13.
Guns—Conventional and Electric	• Develop a medium-caliber EM gun with 0.3 MJ muzzle energy, 15-round salvo, and 300 rnds/min. • Demonstrate direct laser ignition of current propellant for artillery application. • Demo 40-50% increased penetration capability for kinetic energy defeat of explosive reactive armor. • OCRs supported: DSA 01; DBS 01A, 02A; MTD 01; EEL 02, 04.	• Synthesize a propellant giving 25% increased in muzzle velocity for tank guns. • Demo objective crew-served weapon prototype with a weight of <38 lb. • Fabricate 10J/g pulse power supply for EM/ETC gun application. • Demo PGMM with first round target kill capability at 15 km. • OCRs supported: DBS 02B, 05A; MTD 02, MTD 05; EEL 06.	• Demo ETC tank gun technologies providing 25-30 MJ muzzle energy and 2.5 km/sec muzzle velocity. • Demo a 200% increase in hit probability at 4 km with 120 mm tank ammunition. • OCRs supported: DBS 16; MTD 26; EEL 07, 13.

(Continued)

Table IV-I-1. Technical Objectives for Conventional Weapons (Continued)

Technology Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Mines/Countermine	• Demo IMF acoustic sensor ability to autonomously detect armored vehicles at >1 km. • Reproduce a vehicle signature to spoof off-route mines up to 100 m away at speeds up to 10 mph. • Ground penetrating radar and IR detectors to find buried metallic and nonmetallic mines. • OCRs supported: DBS 04A, MTD 04; EEL 08.	• Using robotic/remote-controlled demolition devices, demonstrate de-mining ability with a 2 to 4 times improvement in cost and speed. • Apply multispectral imaging, ground penetrating radar, and chemical/nuclear sensing in a vehicle-mounted detector to find buried, metallic and nonmetallic mines. • OCRs supported: DBS 22; MTD 25.	• Utilize high-clutter targeting algorithm and high speed processors to recon a minefield with high rate of search (50 sq mi/hr). • Demo rapid clearing and 100% detection of mines. • OCRs supported: MTD 04; MTD 25.
Warheads/ Explosives and Rocket/Missile Propulsion	• Demo a tactical version of a selectable-mode EFP warhead at long standoff. • Demo a tactical air-breathing missile with a three-to fourfold increase in range. • Demo low signature gel motor. • OCRs supported: DSA 01; MTD 01; EEL 02.	• Develop an insensitive, minimum smoke rocket propellant for use in LOSAT. • Demo a tactical sub-projectile for the KE precursor warhead that meets aerodynamic and terminal requirements. • Use recrystallization and coatings to produce higher performance, but less sensitive deformable explosives. • OCRs supported: DSA 02; MTD 02; EEL 06.	• Reduce emissions from explosives production processing and demiling by 90%. • Develop improved synthesis procedures to reduce explosives manufacturing costs by 50%. • Reduce aimable/ adaptable warhead size by 10%. • Extend propulsion systems shelf life to more than 25 years. • OCRs supported: DSA 03; MTD 05; EEL 13.
Weapon Lethality/ Vulnerability	• Develop first generation models to predict and analyze penetration of emerging composite materials. • Develop model for stochastic analysis of fragment effects. • Upgrade L/V models to enhance wargame fidelity of the Distributed Interactive Simulation Network. • OCRs supported: DSA 05; DBS 06; MTD 10, 13.	• Develop and validate methodology to predict penetration by hypervelocity (400-1300 m/s) weapons. • Improve body-to-body impact models for tactical ballistic missile targets. • Demo first-order shock propagation model for high-explosive blast loading. • OCRs supported: DSA 06; DBS 08; MTD 13, 15.	• Decrease software preparation time by a factor of 5; improve fidelity by a factor of 2; reduce life cycle costs of conventional weapons by a factor of 2. • Incorporate large-scale hypervelocity penetration mechanics of geological and layered structural materials. • Develop fire/thermal and toxic fume transport model. • OCRs supported: MTD 27, 30; EEL 09.

J.

Electron Devices

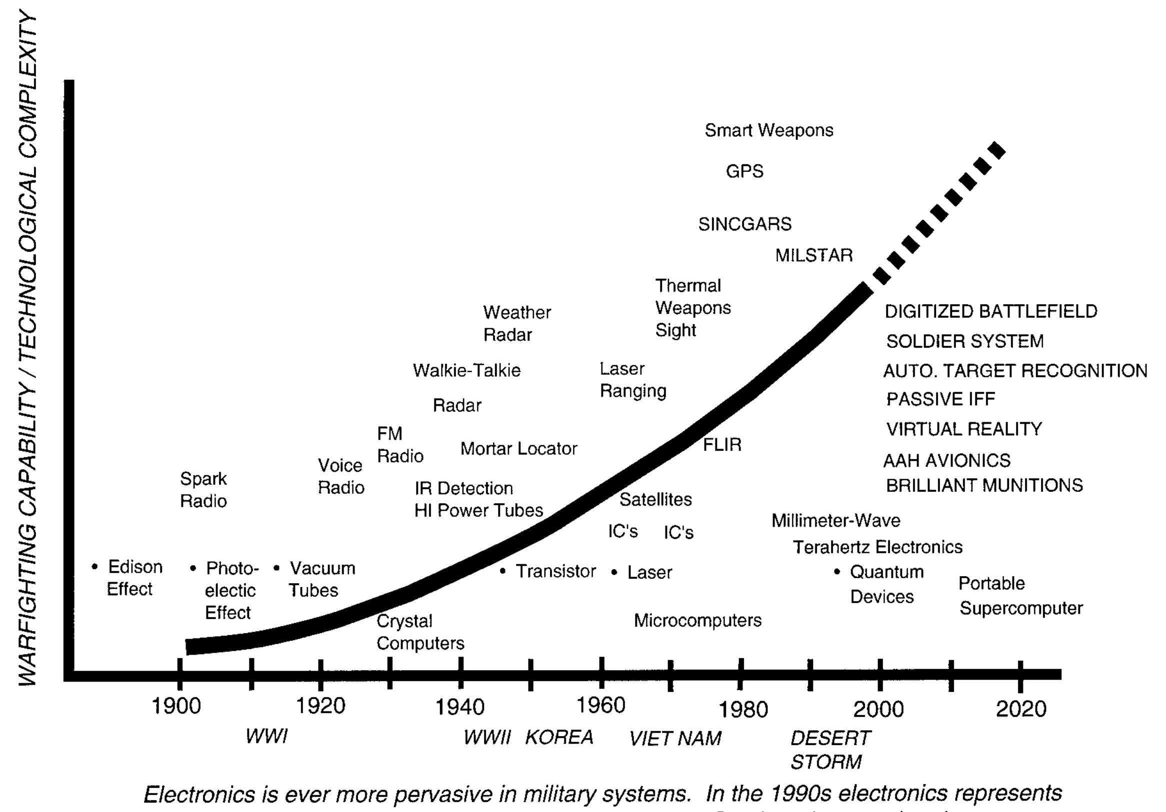
1. Scope

The Electron Devices Technology Area conceives and enhances the billions of ultraminiature components that constitute the nerves and brains of the digitized battlefield. The Army program generates the cutting-edge components essential for a vital advantage over complete dependence on widely available commercial electronics. This Technology Area capitalizes on basic research in the forefront of science (Chapter V), and advances it to the exploratory development subsystem level. It includes focused research, development, and design of electronic materials; nanoelectronic devices, including digital, analog, microwave, and optoelectronic circuits; electronic modules, assemblies, and subsystems; and the required batteries. The Electron Devices Technology Area comprises four major sub-areas: Electro-Optics, Millimeter-Wave Components, Nanoelectronics, and Portable Power Sources.

2. Rationale

Supremacy in Electron Devices is crucial to supremacy on the digitized battlefield. A superior, versatile, innovative program in electron device science and technology is essential to the broad Army vision of (1) decisive force multiplication with a minimum number of platforms and personnel, and (2) avoidance of potentially disastrous technological surprise on the battlefield. The technology supports the Army Five Modernization Objectives, Science and Technology Objectives, and Advanced Technology Demonstrations. The requirements of Army systems such as EW, radar, and C4I translate into component requirements, which may include performance, weight, size, radiation hardness, interoperability, cooling, power consumption, maintainability, and survivability. Surprisingly, this technology area represents over 40 percent of the procurement cost of many military systems. Military purchases of

Figure IV-J-1. Impact of Electron Devices on Warfighting



Electronics is ever more pervasive in military systems. In the 1990s electronics represents about 40 percent of the investment in military systems. Continued research to keep costs down is vital.

semiconductor electronics have increased by an estimated 25 percent from 1992 to 1996. Since total military procurement declined dramatically in those years, semiconductor electronics were one of the very few areas to experience significant growth. Fielding of weapons systems that meet present requirements, that can be upgraded to meet future requirements, and that have affordable life cycle costs will demand exploitation of commercial electronics whenever possible, plus development of the special technologies here for Army systems which need unique capabilities.

3. Technology Subareas

a. Electro-Optics

Goals and Time Frames

The objective of the Electro-Optics subarea is to develop critical electro-optical components such as lasers, focal plane arrays, amplifiers, detectors, photonic devices, fiber optics, and low power displays for application in Army tactical and strategic systems. Near-term goals include development of affordable high resolution, full-color displays for Land Warrior head-mounted vision systems, realization of affordable multispectral FPAs, and economical fiber-optic distributed sensors, LIDARs, and optical countermeasures. Mid-term goals include development of smart multicolor staring focal plane arrays for robust seekers and acquisition sights, and 2-megapixel displays. Long-term goals include development of integrated multi-domain (LIDAR, focal plane array, millimeter-wave) smart sensor elements, and new display technologies.

Major Technical Challenges

Technical challenges include development of more reliable, higher efficiency, higher frequency, longer wavelength solid-state lasers; optical signal processors; cost-effective modules for information systems and IRFPAs; receive-architecture for optically fed phased-array radar; new low-power flat-panel display and driver technologies; and monolithic integration of optoelectronic devices on silicon.

b. Millimeter-Wave Components

Goals and Time Frames

Near-term goals are to insert affordable monolithic microwave integrated circuits (MMIC) into low-cost expendable decoys, low-cost MTI radar, and multifunction active array systems; mature and affordable millimeter-wave IC technology for next-generation, active-aperture systems; and millimeter-wave satellite communications. Mid-term goals are to continue cost reduction and increase the density and functional capabilities of MMIC assemblies and packages, extend microwave power module (MPM) technology to the millimeter-wave frequency regime, and provide common, secure, jamproof, affordable wireless communications, and battlefield friend-or-foe identification. Long-term goals are to achieve unprecedented levels of force multiplication through massive integration of diverse sensors that reduce system size and weight by an order of magnitude while meeting military cost, performance, reliability, and radiation hardness requirements. In brief, the overall goal is to own the battlefield electromagnetic spectrum.

Major Technical Challenges

Among the technical challenges in millimeter-wave components are the achievement of high power; high efficiency; large dynamic range; wide bandwidth; flexible manufacturing modeling and simulation, enabling first-pass success of components, modules, and arrays; and process integration necessary for high-yield, low-cost multifunctional solid-state devices and vacuum tubes. All these attributes must be provided at an affordable cost.

c. Nanoelectronics

Goals and Time Frames

Near-term goals include development of scalable manufacturing processes and cluster and lithography tools for flexible fabrication of integrated compound semiconductor devices; advanced process synthesis technology; novel devices for very high-throughput digital signal processors; integration of electronic combat and combat-support functions; wide-bandgap semiconductor devices for high-temperature electronics; pulse power electronics; nonvolatile memories; and microscale electromechanical components. Mid-term goals include development of lithography and fabrication capabilities for low-volume, affordable integrated microwave, digital, and optical processors. Long-term goals include flexible and affordable fabrication capabilities for concept demonstrations of fully integrated, nanometer feature size, ultra dense circuits for revolutionary warfighting sensor and information systems capabilities.

Major Technical Challenges

Among the technical challenges are creating new wide-bandgap semiconductor devices for high-temperature electronics and for low-leakage, high-breakdown, highly linear power devices; high-quality, radiation-hardened devices of diverse technologies; mixed-signal operation of nanoelectronics with on-chip millimeter-wave and electro-optic components; very low power circuits; and affordable custom nanoscale semiconductor processing for unique military applications-specific circuits. An overall major challenge is the development of high-performance, low-power electronic systems for a substantial reduction in battery requirements and associated weight and size penalties.

d. Portable Power Sources

Goals and Time Frames

The objectives of this program are to lighten the soldier's burden, provide critical pulse-power components, and reduce logistical and disposal costs. This can be done by applying the physical sciences of energy conversion, electronics, signature suppression to improve existing power systems and to enable the development of newer, more advanced battery, fuel cell, capacitors, and electromechanical (including engines and permanent magnet alternators) components and systems.

The general goal is to develop small, lightweight, low-cost, environmentally compatible power sources with high power and energy densities for communications, target acquisition, combat service support applications, miniaturized displays, and microclimate cooling for the Future Soldier System.

Specific near-term goals are:

- Economical, higher energy (150 Wh/kg) lithium (Li) batteries for man-portable equipment
- Lighter weight, higher energy density (80 Wh/kg) metal hydride or Li-ion rechargeables
- Improved spin-stable reserve batteries
- Reduced cost electrochemical capacitors
- Man-portable 150 Watt fuel cells for Soldier Systems
- Man-portable (40 lb/kW), signature suppressed 3000 Watt engine driven generator set. The engine shall have a BSFC of 0.7 and thermal efficiency of 20 percent and will be capable of starting and operating on DF-2/JP-8 fuels.

Specific mid-term goals are:

- Higher power density (350 Wh/kg) Li primary batteries
- Improved energy (100 Wh/kg) rechargeable batteries
- Electrochemical capacitors for electric vehicles
- Fuel cell stacks which operate on liquid fuels
- Demonstration/validation of signature suppressed, electronically controlled, man-portable/man-handleable 0.5-3.0 kW engine driven generator sets that provide power on the move, enhance total asset visibility and CSS operations and are compatible with emerging C4I and weapons systems.

Specific long-term goals are:

- Higher energy (150 Wh/kg) rechargeable Li batteries
- Practical silent thermophotovoltaic power sources
- 1-50 kW transportable fuel cells
- Portable 5000 Watt diesel engine driven generator set compatible with emerging C4I and weapons systems
- Demonstration of dual use electromechanical (power generation, transmission, distribution, or utilization) technologies and equipment (0.5-1100 kW) which reduce system size/weight and visual/audible IR signatures, improve system reliability, minimize operation and support costs, and improve the deployability, tactical mobility, and effectiveness of a CONUS-based fighting force.

Major Technical Challenges

Nonflammable, high-conductivity electrolytes and lower-cost manufacturing methods for Li batteries, improved fabrication methods for metal hydride cells, improved current collection from carbon fibers in electrochemical capacitors, polymer exchange membranes for fuel cells that retain conductivity at high temperatures, and spectrally-matched emitters and photocells for thermophotovoltaic systems, and higher efficiency combustion of and greater reliability/life for man-portable/man-handleable engine driven generator sets.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Electron Devices is shown in Table IV-J-1, below.

Table IV-J-1. Technical Objectives for Electron Devices

Technology Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Electro-Optics (Photonic Devices)	• Order of magnitude improvement in spatial light modulator dynamic range. • Optical interconnect for computer. • Photonic and electronic devices integrated on the same chip. • Image-forming light modulator in a hybrid (digital-optical) automatic target recognizer and infrared projector. • Improve producibility of the deformable mirror image-forming light modulator. • Modulation of RF signals with laser diodes. • OCRs supported: BC 02, 03, 04, 06, 07, 08; DSA 03, 08, 09, 16, 17, 18; DBS 18; MTD 02, 09, 15, 16; EEL 11, 12.	• Integrated opto-electronic staring laser radar. • Optically controlled phase arrays. • Integrated photonic/ electronic/ microwave and IR devices. • Image-forming light modulator in a pure optical automatic target recognizer. • Matured technology base in the synthesis and characterization of electro-optical materials. • OCRs supported: BC 02, 03, 04, 06, 07, 08; DSA 03, 08, 09, 16, 17, 18; DBS 18; MTD 02, 09, 15, 16; EEL 11, 12.	• On-chip, massive optical interconnects. • Image-forming light modulator with completely integrated construction . • Integration with multi-band sensors and neural processing. • Autonomous devices for ATR and fire control in microwave band sensors. • Optical computers. • Massively parallel architectures. • OCRs supported: BC 02, 03, 04, 06, 07, 08; DSA 03, 08, 09, 16, 17, 18; DBS 18; MTD 02, 09, 15, 16; EEL 11, 12.
Electro-Optics (Fiber Optic Technology)	• Multiplexed fiber-optic sensor. • Discrete components for fiber-optic gyros. • Environmentally stable fiber-optic dispensers. • Manufacturing process for interferometric fiber-optic gyros (IFOG). • OCRs supported: BC 01, 02; DSA 03, 05, 12, 14; MTD 01, 10, 16, 18, EEL 01, 04.	• Distributed fiber-optic sensor with 10 times as many acoustic channels. • Miniature integrated chip components. • Highly reliable miniature (3-axis) IFOG. • Efficient coupling techniques for miniature components. • Fiber-optic strain-sensing techniques. • Integrated photonic subsystems. • OCRs supported: BC 01, 02; DSA 03, 05, 12, 14; MTD 01, 10, 16, 18; EEL 01, 04.	• Highly reliable IMU on-chip resonant fiber-optic gyro. • Demonstration of fiber-optic gyro. • Demonstration of small, ultra long-range, fiber-optic data links. • OCRs supported: BC 01, 02; DSA 03, 05, 12, 14; MTD 01, 10, 16, 18, EEL 01, 04.
Electro-Optics (Smart Multi-Spectral Detectors and Sources)	• Ultra-wideband passive microwave/MMW sensors. • Pre-detection single frequency band sensor fusion. • Thin-film uncooled ferro-electric IR detector. • Efficient direct energy source in visible wavelength region. • Improved passive LWIR detectors. • High resolution image intensification (I^2) devices. • OCRs supported: BC 01; DSA 12; DBS 01, 02B, 08; MTD 01, 16; CSS 17.	• MOMBE producible SMART multi-color FPA with image processing functions. • Uncooled FPA with NE DT<0.01°C for F/1 system. • Long-life, blue-green laser diode operation at room temperature. • Nonlinear optical devices for sensor protection. • Efficient laser source at 3-5 mm. • Smart multi-color FPA producibility. • OCRs supported: BC 01; DSA 12; DBS 01,02B, 06, 08; MTD 01, 11, 16; CSS 07, 17; EEL 06, 13.	• Monolithic multi-function, multi-spectral (including mm wave) smart FPA. • Smart, uncooled FPA. • Broadband, low cost, low loss, visible, passive sensor protection. • Portable, tunable counter-measure source. • Portable, tunable solid state visible laser source. • OCRs supported: BC 01; DSA 12; DBS 02B, 08, 14; MTD 11, 16; CSS 07, 17; EEL 06, 13.

(Continued)

Table IV-J-1. Technical Objectives for Electron Devices (Continued)

Technology Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Electro-Optics (Smart High-Resolution Displays)	• High-resolution, full-color flat-panel displays for tactical environments. • 1000X 1000 head mounted display. • OCRs supported: BC 05, 06, 07. 11; DA 07; MTD 15, 16, 18.	• Miniature high-resolution displays for tele-presence and virtual environment applications. • 2000X 2000 head mounted display. • OCRs supported: BC 05, 06, 07, 11; DA 07; DBS 10, 21, 25.	• Real-time holographic (3D) displays. • Video capabilities. • OCRs supported: BC 05, 06, 07, 11; DSA 07; DBS 21, 25; EEL 11, 12.
Electro-Optics (Millimeter, Wave, IR Sensor Processors)	• Prototype super-conductor detectors. • Integrated IR sensor and processor. • Passive super-conducting microwave components with IR systems. • Computer-aided design of FLIR-based upon EO parameters. • Quantum-well arrays. • OCRs supported: BC 01, 05, 08; DSA 03, 07, 09, 12, 14, 18; DBS 03, 13, 16; MTD 01, 02, 16; EEL 01, 04, 05 12.	• LWIR FLIRs based on HgCdTe, superlattices, and super-conductor materials. • Integration of FLIR and processor into multicolor monolithic detectors. • Active/passive high temperature superconducting for dual mode systems. • Fusion of multiple wideband sensors. • 2000X 1000 quantum-well staring arrays. • OCRs supported: BC 01, 05, 08; DSA 03, 06, 07, 09, 12, 14, 17, 18; DBS 03, 13, 16, 18; MTD 01, 02, 07, 16; EEL 01, 04, 05, 12.	• Far IR goggles. • 2D array of superlattice long-wave detectors. • OCRs supported: BC 01, 05, 08; DSA 03, 06, 07, 09, 12, 14, 17, 18; DBS 03, 13, 16, 18; MTD 01, 02, 07, 16; EEL 01, 04, 05, 12.
Millimeter-Wave Components (Analog MIMIC Devices)	• Continuous increases in single radar-type function (amplifiers, oscillators, mixers, switches) chips in the 1 to 140 GHz range. • Cost reduction of chips. • OCRs supported: BC 06, 08; DSA 03, 09, 12; DBS 03, 13, 14, 21, 25; MTD 02, 09, 15; EEL12.	• Microwave/digital ICs. • Microwave/optical ICs. • Vehicular radar. • MMW wireless communications. • High-density 3D packaging. • High-power vacuum devices. • OCRs supported: BC 06, 08; DSA 03, 06, 09, 12; DBS 03, 13, 14, 21, 25; MTD 02,07, 09, 15; EEL 12.	• Full integration of MIMICs with digital and opto-electronic devices in the 100 to 200 GHz range. • OCRs supported: BC 06, 08; DSA 03, 06, 09, 12; DBS 03, 13, 14, 21, 25; MTD 02, 07, 09, 15; EEL 12.
Millimeter-Wave Components (High-Power Terahertz Sources)	• Demo Ka-Band power amplifier for missile seekers. • Broadband subMMW amps for advanced weapon systems. • Terahertz spacedemo. • OCRs supported: DSA 09, 12; DBS 03; MTD 01; EEL 01, 04.	• High-efficiency Ka-band compact amplifiers. • Prototype sub MMW amps. • High-power terahertz source for space applications. • Low-power-consumption terahertz/sub MMW. • OCRs supported: DSA 12, 14; DBS 14, 25; MTD 01, 09.	• Extension of terahertz sources to infrared spectral region. • OCRs supported: DSA 12, 14; MTD 01, 10; EEL 01, 04.

(Continued)

Table IV-J-1. Technical Objectives for Electron Devices (Continued)

Technology Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Millimeter-Wave Components (Acoustic-Wave Devices)	• Family of ultra-stable low noise frequency sources. • High-performance frequency channelizer. • OCRs supported: BC 07, 09; DSA 03, 07, 09, 19; MTD 01, 05, 09.	• Miniature atomic frequency standards. • Fully adaptive bandpass/ bandstop filters. • Chem-Bio Sensors. • Vibration-resistant oscillators. • Miniaturized filters/resonators. • Low cost ID tags. • Analog/digital hybrid processors. • Non-reciprocal acoustic components. • OCRs supported: BC 07, 09; DSA 03, 07, 09, 19; MTD 01, 05, 09.	• Multicolor IR sensors, accelerometers. • Thin-film and other monolithic resonators/ acoustic components integrated with MMIC transceivers. • Automatic micro-computer compensation and laser-aided fabrication error correction. • Miniaturized frequency channelizer. • Accelerometers. • OCRs supported: BC 07, 09; DSA 03, 07, 09, 19; MTD 01, 05, 09.
Nanoelectronics (Compound Semiconductor Manufacturing)	• Advancement of MOMBE and MOCVD single-wafer deposition technology. • Development of SiC process technology for high temperature electornics and power devices. • Ferroelectric film development for nonvolatile memory applications. • OCRs supported: BC 04, 05, 06, 07, 008; DSA 01, 02, 03, 09, 18; DBS 03, 07, 14, 16; MTD 01, 02, 14; EEL 01, 04, 05, 12, 13.	• Development of reliable sources of InP wafers. • Heteroepitaxial growth of device-quality GaAs on Si. • Development of wide bandgap SiC devices for high tempera-ture and high power applications. • Ferroelectric nonvolatile memories for digital battlefield applications. • OCRs supported: BC 04, 05, 06, 07, 08; DSA 01, 02, 03, 09, 18; DBS 03, 07, 14, 16; MTD 01, 02, 14; EEL 01, 04, 05, 12, 13.	• Development of GaN materials and devices. • OCRs supported: BC 04, 05, 06, 07, 08; DSA 01, 02, 03, 09, 18; DBS 03, 07, 14, 16; MTD 01, 02, 14; EEL 01, 04, 05, 12, 13.
Nanoelectronics (Integrated Optics)	• Process for growth and characterization of electro-optical polymers. • Device functions in electro-optical polymers. • Nonlinear materials and demonstrate limiting and thresholding operations. • OCRs supported: BC 02, 03, 04, 08; DSA 03, 08, 10, 15, 16, 17, 18; DBS 18, 20; MTD 09, 16, 17, 30; EEL 11.	• Process for growth and characterization of indium phosphide. • Integrated optics device functions in indium phosphide. • Selective technology insertion of integrated optics functions based on electro-optical polymers. • OCRs supported: BC 02, 03, 04, 08; DSA 03, 08, 10, 15, 16, 17, 18; DBS 18, 20; MTD 09, 16, 17, 30; EEL 11.	• Technology insertion of selected integrated optics functions. • High speed digital (soliton) coupling and logic operation devices. • OCRs supported: BC 02, 03, 04, 08; DSA 03, 08, 10, 15, 16, 17, 18; DBS 18, 20; MTD 09, 16, 17, 30; EEL 11.

(Continued)

Table IV-J-1. Technical Objectives for Electron Devices (Continued)

Technology	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Nanoelectronics (Micromechanical Actuator-Sensors)	• Micromachined structures and materials for miniature sensors and actuators. • Micro-acoustic sensors for target detection and chemical/ biological sensing. • Miniature gyroscopes and accelerometers for inertial guidance. • OCRs supported: BC 01, 08; DSA 03; DBS 02A, 10, 16; MTD 01, 16; EEL 01, 04.	• Miniature medical instruments for surgery. • Monolithically integrated miniature sensor/actuator microsystems. • Integrated sensor readout circuits for real-time information output. • OCRs supported: BC 01, 08; DSA 03; DBS 02A, 10, 16; MTD 01, 16; EEL 01, 04; CSS 07, 08.	• Embedded microsensors and actuators for automated missile guidance, structural failure prognosis, personal navigation, and medical diagnosis/ treatment. • OCRs supported: BC 01, 08; DSA 03; DBS 02A, 10, 16; MTD 01, 16; EEL 01, 04; CSS 07, 08.
Portable Power Sources	• Low-cost primary Li battery, 150 Wh/kg. • Improved energy density metal hydride or Li-ion rechargeable batteries, 80 Wh/kg. • Low-cost electrochemical capacitor, replacing platinum metals with carbon. • Man-portable 50/150W fuel cell systems (100 W-hr/kg). • Deliver GPS missile battery. • Improve design of spin-stable thermal batteries. • OCRs supported: BC 06, 08; CSS 17; DSA 03: DBS 20, 21.	• Advanced primary Li battery for Soldier System, 350 W/kg. • Improved energy density rechargeable batteries, 100 Wh/kg. • 20 kW, 500 kJ electrochemical capacitor for electric vehicles. • Man-portable 50/150W fuel cell systems (200 W-hr/kg). • OCRs supported: BC 06, 08; CSS 17; DSA 03; DBS 25.	• Advanced Li rechargeable, 150Wh/kg. • Practical thermophoto-voltaic charger using logistic fuels. • Advanced, polymer or solid-oxide fuel cell, up to 50 kW. • OCRs supported: MDT 05, 16, 25; EEL 11.
Electromechanical Technologies	• Man-portable, signature suppressed 3000 W (40 lb/kW) engine driven generator set capable of burning JP-8/DF-2. • OCRs supported: BC 23, 24; CSS 18, 19, 20; DBS 09, 23, 24, 25; MTD 03, 06, 18, 20.	• DEM/VAL signature suppressed, electronically controlled man-portable/ man-handleable 500–3000 W engine driven generator sets • OCRs supported: BC 23, 24; CSS 18, 19, 20; DBS 09, 23, 24, 25; MTD03, 06, 18, 20.	• Man-portable, signature suppressed, electronically controlled 5000 W (70 lb/kW) engine driven generator set capable of burning JP-8/DF-2. • Dual use electromechanical technologies and equipment (0.5–1.1 kW) which will reduce system size/weight and signatures, improve system reliability, tactical mobility, and effectiveness of CONUS-based force. • OCRs supported: BC 23, 24; CSS 18, 29, 20; DBS 09, 23, 24, 25; MTD 03, 06, 18, 20.

K.

Electronic Warfare/ Directed Energy Weapons

1. Scope

Electronic Warfare includes any military action involving the use of electromagnetic and directed energy to control the electromagnetic spectrum or attack an enemy. Electronic warfare comprises three major subdivisions: Electronic Attack—use of electromagnetic or directed energy to attack personnel, facilities, or equipment with the intent of degrading, neutralizing, or destroying enemy combat capability; Electronic Support—actions taken by, or under direct control of, an operational commander to search for, intercept, identify, and locate sources of radiated electromagnetic energy for immediate threat recognition in support of EW operations and other tactical actions such as threat avoidance, homing, and targeting; and Electronic Protection—actions taken to protect personnel, facilities, or equipment for any effects of friendly or enemy employment of electronic warfare that degrade, neutralize, or destroy friendly combat capability. Electronic warfare and directed warfare are leading technologies for solving Army problems in scenarios where non-lethal (i.e., no permanent injury) or less than lethal (i.e., could suffer serious injury) force is required.

Figure IV-K-1 illustrates DEW and jamming applications on the battlefield. Figure IV-K-2 depicts the electronic power relationships between electronic warfare jammers and RF-directed energy weapons.

2. Rationale

As the roles, missions, and capabilities of today's Army evolve into the 21st century, so then does the role of electronic warfare. Dominance of the electromagnetic spectrum based on the ability to use and deny its use by others at will is dependent on industry, academia, the other services, and a robust program to sustain the Army's unique requirements on the electronic

Figure IV-K-1. Battlefield Applications of DEW and Jamming

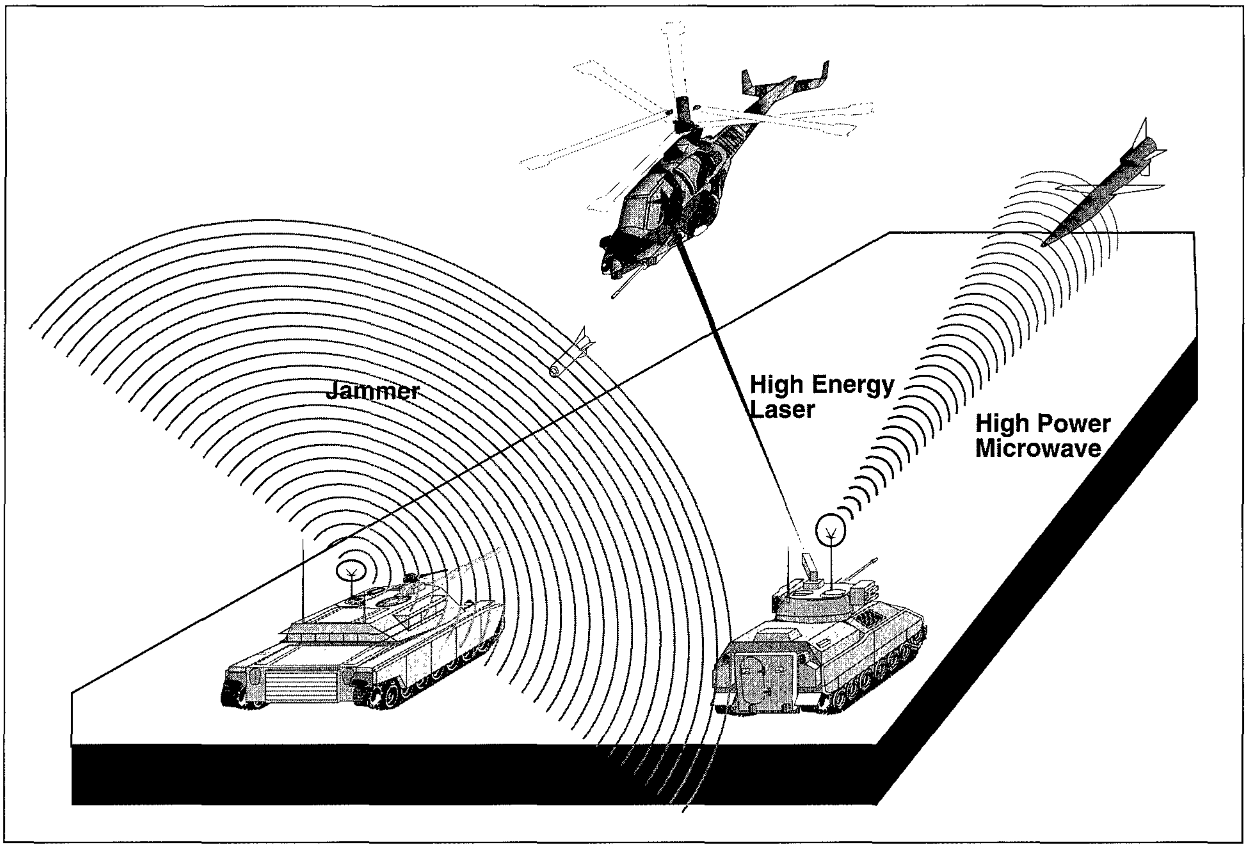
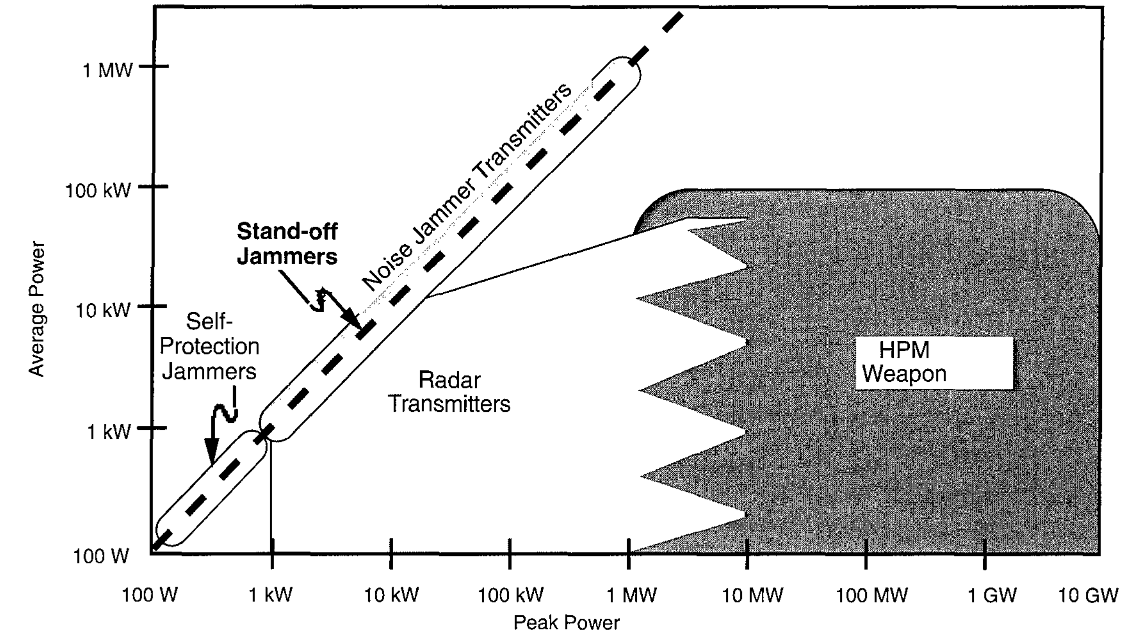


Figure IV-K-2. Comparison of EW Jammer and RF-DEW Power Relationship



battlefield. As threat systems become more complex, the need to develop EW systems that can respond to changing environments is critical to superior battlefield surveillance and survivability. Technology to collect, recognize, and process complex wave forms and provide effective jamming are essential. Knowledge-based systems using artificial intelligence and adaptive parallel distributed processing can provide "smart" software control to maintain an edge on a dense signal battlefield.

3. Technology Subareas

a. Electronic Attack

Goals and Time Frames

Develop the technologies that provide the capability to intercept and bring under electronic attack advanced communications signals being used by adversarial command and control networks on the digital battlefield. Through electronic attack strategies demonstrated with prototype hardware and software, these digital communications signals will be disrupted, denied, and/or modified to render the communications system ineffective and unreliable to the threat command and control function. Near-term goals are to demonstrate electronic attack against a set of digital formats being implemented in commercial communications systems and data transmission systems. Mid-term goals are to demonstrate the ability to disrupt other commercial communication networks and wide bandwidth communications. Long-term goals include the ability to surgically attack specific users in a non-obtrusive means while maintaining the overall integrity of the targeted communications network.

Development of sensor and countermeasure technologies is a complex "chess game" of trying to outplay your opponent, betting that your defensive systems can outmatch their offensive capabilities. Advanced technology and tactics are the last line of defense where a time span of two seconds or less can mean the difference between winning or losing. Technology goals include development of multifunctional/multispectral infrared countermeasures, radar and laser warning, and countermeasures that can provide both self/area protection of air and ground platforms, as well as targeting and real-time situational awareness at the fighting station(s). Near-term goals include demonstration of a beam coupler for the DARPA laser/anti-tank IRCM point/tracker, the evaluation of IRCM techniques for top attack threats for ground vehicles, and the demonstration of an RF sensor and ECM modulator with the capability to locate, deceive, and jam monopulse and phased array radars from UHF through millimeter wavebands. Mid-term goals include development of countermeasures for advanced EO/IR missiles using imaging seekers, and the continued development of advanced RF countermeasures with low cost finger-printing for signal sorting, jamming, targeting, and combat identification. Long-term goals include initiatives to develop integrated RF/IR/laser sensors and countermeasures against advanced EO/IR surface-to-air missiles and horizontal/top attack smart munitions.

Major Technical Challenges

The increasing use of common carrier commercial communications networks by potential adversaries presents the major technical challenge. We must be able to separate the threat-relevant communications from the pure commercial traffic and perform effective electronic warfare without disrupting the entire network. These targeted communication systems are characterized as adaptive sophisticated digital networks and modulation schemes that employ various layers of protocol and user protection.

Technology challenges include development of uncooled, low false alarm rate detectors with <1 degree AOA accuracy, development of multicolor IR focal plane arrays (Navy/Air Force Program), missile detection algorithms, and development of more efficient, low-cost, temperature stable IR/UV filters. The development of advanced high speed wideband digital receivers using GaAs microscan design approach, and the development of high power ultra-wide band jamming modulators and transmitter sources from A through M bands using MPM, MMIC, and fiber-optic remoting of sensors and transmitters. Precision AOA for situational awareness and targeting.

b. Electronic Support

Goals and Time Frames

As modern communication systems evolve, the overall goal is to develop the technology required to provide an ES/EA capability to intercept and counter these new priority threats and to provide the battlefield commander the tactical intelligence products that contribute to his ability to accomplish his mission. Near-term goals include the downsizing of existing bulky components to provide a rapidly deployable capability and the conversion from special purpose processors and software to a general purpose suite. The intent is also to provide the ability to specifically tailor and reprogram these systems quickly either locally or remotely to meet the current and changing threat. Mid-term goals include development of signal processing techniques that provide effective ES against common carrier, multiple access commercial communications in order to identify, locate, and exploit threat users. A second goal is the development of the tools required to display increasingly complex data to the soldier operators in support of the IEW mission. The long-term goal includes the continued development of adaptive sensor technologies that can perform the ES mission as the use of increasingly more complex communication systems continues to evolve.

Major Technical Challenges

The increasing use of common carrier commercial communications networks by potential adversaries presents the major technical challenge. This infers the need for advanced front end receiver architectures and signal processing techniques capable of providing ES mission functions against increasingly complex signal modulation methods and structures coupled to higher data rates and user protection schemes.

c. RF-Directed Energy Weapons

Directed Energy Weapons (DEW) include laser, high power radio frequency (HPRF), and particle beam technologies. HPRF technology is frequently called high power microwave (HPM) or RF-Directed Energy.

Electronic equipment can be defeated or impaired by irradiation from Directed Energy (DE) sources. Degradation can range from: (1) temporary "upsets" in electronics subsystems, (2) permanent circuit deterioration, or (3) permanent destruction due to burnout or electrical overload. As modern systems and their components become ever more reliant on sophisticated electronics, they also become more vulnerable to DE radiation. The Army's DE program priority is to assess potential vulnerability of U.S. systems to unintentional irradiation "fratricide" by our DE capable systems as well as intentional irradiation by enemy DE systems. DE hardening technology is being developed to mitigate both of these threats. In addition, the Army S&T program provides sources and components to (1) support the susceptibility assessment program, (2) support possible future applications, and (3) avoid technological surprise from an adversary's breakthrough.

Goals and Time Frames

Near-term goals for RF-DE weapons are (1) the demonstration of the interference modulation HPM source concept for use in susceptibility testing and in field tests, and (2) RF-DE weapons hardening for MMIC circuits used in Army systems. A mid-term goal is the development of High-Gain, broadband antennas. Long-term goals include development of silicon carbide hardening devices and use of chaos theory research results to achieve greater control of RF-DE weapon sources.

Major Technical Challenges

High power RF generators need to be smaller, lighter, and more fuel efficient. Projected targets require intensive susceptibility studies to determine the best attack methods. These technical challenges will be overcome by concentrating technology development efforts on improving modulators, RF sources, and antennas. Improvements to reduce size, weight, and power requirements must also be accomplished by enhancements to radiate beam control.

d. Lasers

Compact, high efficiency lasers are critical for electro-optical countermeasures (EOCM), infrared countermeasures (IRCM), and directed energy (DEW) applications. The maturation of diode pumped lasers, nonlinear frequency conversion techniques, and advanced laser design has made feasible the incorporation of these devices into tactical vehicles and aircraft for self-protection and missile defense. The challenge is to demonstrate the required power levels in a compact package for Army applications and to scale the power to higher levels for future needs.

Goals and Time Frames

One FY96 goal was to demonstrate compact mid-infrared lasers to meet an Army ATD requirement. This was accomplished under a DARPA/Tri-Service program that increased power by an order of magnitude. Optically and electronically pumped solid-state lasers that will transition to EMD by FY00 should have significantly lower cost, size, and power comsumption. These lasers are being developed under a management agreement between DARPA and the Services. An Active Tracker System was developed under another DARPA program for IRCM/EOCM applications to provide precision pointing and atmospheric compensation. This technology was demonstrated in FY96. The DARPA/Army 10 Joule/100 Hz diode pumped laser (DAPKL) was demonstrated in the lab in FY95 and is scheduled to be packaged for delivery in FY97.

Major Technical Challenges

The major challenge to scaling the mid-infrared lasers is the development of an Optical Parametric Oscillator (OPO) which can handle the higher average powers without damage. Other issues are the packaging of lasers for use on aircraft and the cost reduction of laser diode arrays. A longer term challenge will be the scaling of compact solid-state lasers to higher powers for standoff directed energy applications.

Specific challenges include:

- Increasing power/weight by threefold for sensor countermeasure systems.
- Scaling the power output of solid-state lasers by 10X to 20X in a compact package.
- Developing direct diode laser sources with wavelengths from blue/UV to mid infrared.
- Reducing the cost of laser diode arrays to less than $1/peak watt.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Electronic Warfare/Directed Energy Weapons is shown in Table IV-K-1, below.

Table IV-K-1. Technical Objectives for Electronic Warfare/Directed Energy Weapons

Technology Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Electronic Attack (Signal Processing)	• 33% reduction in processing time; power efficiency increase 33%; size reduction 25%. • OCRs supported: BC 01, 17; MTD 03, 09; DSA 01; DBS 13; EEL 01.	• Increase number of signals tracked by 200%. • OCRs supported: BC 17.	• 50% increase in processing speed and computations per second. • OCRs supported: BC 17.
Electronic Support (Receivers)	• Improved dynamic range 20%. • OCRs supported: BC 17.	• Size reduction 50%. • OCRs supported: BC 17.	• 8:1 reduction in size and power. • OCRs supported: BC 17.
Electronic Attack (Antennas)	• Improved broadband HF/VHF passive antenna efficiency by 10%. • E-J Band Precision AOA, Polarization insensitive. • OCRs supported: BC 17.	• Improved efficiency >30%, size reduction 90%. • A-K Band. • High gain, high power ground band antennas. • OCRs supported: BC 17.	• 40% improvement in HTSC material operating conditions. • Integrated A-M band, laser warning, EO/IR FPA. • OCRs supported: BC 17.
Electronic Attack (Radar Jamming Techniques & Modulators)	• Jam monopulse and phased array, DRFM 200 MHZ BW. • OCRs supported: BC 17.	• Phase 0 Array and Spread Spectrum radars DREM 1 GHz BW. • OCRs supported: BC 17.	• Impulse and Bi-Static Radars DRFM 10 GHz BW. • OCRs supported: BC 17.
Electronic Attack (Fuze/Smart Munition Jamming)	• Precision DRFM, 50 picosec in 10 Hz steps. • OCRs supported: BC 17.	• Precision DRFM, 5 picosec in 1 Hz steps. • OCRs supported: BC 17.	• Precision DRFM, 1 picosec in sub HZ, 1 GHz BW. • OCRs supported: BC 17.
Electronic Attack (Fiber Optic Cable for IRCM/Laser Warning)	• Mid IR < 1 dB/m. • OCRs supported: BC 17.	• Mid IR, Visible < 1 dB/m. • OCRs supported: BC 17.	• Mid-Long IR, Visible < .5 dB/m. • OCRs supported: BC 17.
Electronic Attack (IR Missile Jamming)	• Mid IR CONSCAN. • OCRs supported: BC 17.	• Mid IR, Visible FPA CM. • OCRs supported: BC 17.	• Mid-Long IR, Visible FPA CM. • OCRs supported: BC 17.
Electronic Attack (Passive Horizontal/ Top Attack Detection)	• Horizontal ATGM. • OCRs supported: BC 17.	• Top Attack Smart Munition. • OCRs supported: BC 17.	• Low observable Horizontal and top attack munitions. • OCRs supported: BC 17.
RF-Directed Energy Weapons	• High power interference modulation source concept. • OCR supported: BC 17.	• Silicon carbide hardening devices. • OCR supported: BC 17.	• Techniques for hardening against upset. • High power wideband amplifiers. • OCR supported: BC 17.
Lasers	• Mid-IR laser source < 50 lb. • Package DAPKL.	• Mid-IR laser with 10X power. • Compact 10X power solid-state laser.	• Lightweight all band mid-IR diode lasers. • Compact 100X power solid-state laser.
High Power Radio Frequency (HPRF)	• Multibeam Klystron • RF-DEW Modulator • OCRs supported: DBS 02B.	• High average power TWT's. • Advanced RF-DEW pulsers. • OCRs supported: BC 20; DSA 06.	• Advanced conventional source systems. • Alternate source weapon systems. • OCRs supported: BC 20; DSA 06; DBS 02B.

DRFM Digital RF Memory
Hz used in this context indicates repetition rate

Note: Technical objectives for capacitors, switches and batteries can be found in the Electronics section.

L.

Civil Engineering and Environmental Quality

1. Scope

Technology effort in this area solves critical environmental and civil engineering problems related to training, mobilizing, deploying, and employing a force at any location at any time. The program will provide the Army with enhanced capabilities to execute mobility, countermobility, survivability and general engineering missions. It also provides the lowest possible environmentally sustainable, life cycle cost, military unique infrastructure required to project and sustain U.S. forces worldwide from CONUS or forward-presence bases.

Environmental quality subareas include Cleanup—of contaminated sites, Compliance—with all environmental laws, Pollution Prevention—to minimize Army's use and generation of wastes, and Conservation—of our natural and cultural resources. Civil Engineering subareas include Conventional Facilities, Airfields and Pavements, Survivability and Protective Structures, and Sustainment Engineering. There is a Tri-Service Joint Engineers Management Panel to oversee, direct, and coordinate this program. The Joint Engineers consists of the flag officer engineer material developer for each Service and is currently chaired by the Air Force under a 2-year rotation assignment. Technology subpanels in each major program area ensure coordination and nonduplication of research efforts.

2. Rationale

National and international laws and treaties demand the mitigation of environmental impacts resulting from normal operations and maintenance of Army training readiness and industrial activities. Base realignment and closure actions place an added urgency on bringing our sites into compliance while placing more activity on remaining installations, thereby creating greater demands on facilities and compliance requirements. Reduced budgets and increased regulatory requirements dictate the need for new or improved technologies that reduce the costs of contaminant cleanup, treatment, and disposal; reduce the generation of hazardous materials and pollutants; enhance compliance; and maintain natural and cultural resources in a realistic state to support training and operations. Payoff for investments in environmental quality technology is realized by reducing the cost of doing business while maintaining our mission readiness without shutdown of activities, expenditure of limited resources resulting from environmental violations.

Civil engineering R&D provides the Army technologies to project and sustain U.S. Forces from CONUS and OCONUS in the defense of this nation. The payoff in this area is threefold: (1) O&M cost reductions free up dollars for mission critical activities; (2) Infrastructure improvements of Power Projection Platforms increases military readiness; and (3) Enhanced quality of life improves Army capability through increases in retention rates for soldiers and their families. Unique Army civil engineering needs arise from the characteristics of the weapons and transportation systems. The requirement to counter the effects of advanced conventional weapons and saboteur threats is not found in the private sector and, accordingly, there is no robust civilian R&D effort. The need to rapidly establish, maintain, and upgrade or retrofit facilities and transportation infrastructure within a theater of operation is unique; the private sector has no like requirement and no significant R&D investment. Our aging CONUS infrastructure (the average age of Army facilities is 35 years) requires modernization on a scale not seen elsewhere.

3. Technology Subareas

a. Environmental Quality

Goals and Time Frames

The primary thrusts of site Cleanup R&D are to reduce cost and expedite cleanup programs, while ensuring protection of human health and the environment. R&D is conducted in Characterization/Monitoring, Remediation Technologies, and Fate and Effects of environmental contaminants in all climates. Cleanup R&D will produce innovative and cost-effective site identification, assessment, characterization, advanced cleanup methods, and monitoring technologies. By 2001, advanced sensors and sampling devices will expand the capabilities and precision of these systems. Subsurface conditions will be better understood, thus increasing the efficiency of composting, UXO detection, in-situ biological treatment, passive subsurface water treatment, and improved chemical immobilization concepts and methods. Techniques will be developed to more accurately and rapidly determine the fate, transport, and effects of key DoD contaminants in soil and groundwater in all climatic conditions.

Compliance R&D will provide numerous technologies for advanced "end-of-the-pipe" control and treatment of hazardous, toxic, gaseous, liquid or solid wastes when pollution prevention is not possible. Army systems, operations, and processes will be developed to meet existing and anticipated air, water, land, and noise regulations. R&D is focused on (1) characterization of pollutant and waste behavior, (2) media specific control and treatment technologies, and (3) monitoring and assessment tools. Pollution Prevention R&D will provide the Army with alternative materials, innovative manufacturing processes, and enhancements to daily activities to enable the Army to continue to operate current and future production plants as well as use its weapons systems. Overall efforts are focused on minimizing of compliance requirements through new systems and processes that prevent or minimize pollution with the attended reduction in production and product treatment costs.

Conservation R&D will provide sustainable support for realistic training and testing operation through improved understanding of natural and military operations processes affecting biological, earth, and cultural resources. R&D is focused on developing cost-effective technologies to mitigate military impacts, rehabilitate damaged resources, comply with environmental regulations, and support sustainable ecosystem management. The goal by the year 2001 is to develop an integrated modeling framework linking land capacity, land rehabilitation, and species/ecosystems impact models.

Major Technical Challenges

Major technical challenges include (1) site heterogeneity (soil, water, and climate); (2) complex mixtures of military-unique chemical compounds encountered at cleanup sites; (3) inherent complexity of physical, chemical, and biological phenomena; (4) density and opaqueness of earth media; (5) difference in acceptable risk; (7) need to understand and develop technologies that address the diversity and complexity of waste streams, composition of wastes, the energetic instability of waste streams, and the destruction or conversion of wastes and contaminants without the production of unwanted or hazardous by-products; and (8) need to adapt military ranges to changes in mission, equipment, and training; and need to understand and manage complex ecosystems and their responses to stress.

Technology Barriers: Army research is currently working to overcome technological barriers in environmental quality by developing technologies and applications such as:

- Supercritical water oxidation, advanced oxidation processes, catalytic decomposition, biodegradation and co-metabolic processes, sorption, separation, and conversion to reduce costs and increase efficacy of treatment and disposition.
- Replacement materials for existing solvents, soluble chromium, strong acids, bases, and oxidizers used in production and maintenance activities.
- Integrated sensors, sampling, modeling, and management technologies to maintain DoD activities while conserving natural and cultural resources which are protected by a variety of statutory requirements.

b. Civil Engineering

Goals and Time Frames

The primary thrusts of the Conventional Facilities area are to develop technologies to revitalize and operate DoD's aging infrastructure, to ensure effective strategic Power Projection Platforms, and to maximize productivity of resources in acquisition, revitalization, operations, and maintenance and repair (M&R) management. The Army's $162 billion physical plant requires $5.9 billion annually to operate, maintain, and repair its aging facilities. The annual energy bill alone topped $1.5 billion, while the Backlog of Maintenance and Repair (BMAR) of facilities is $2.2 billion. The goal is to achieve a 20 percent reduction in facilities acquisition and M&R costs from 1990 levels and a 30 percent reduction from 1985 levels in energy consumption by FY 2005. Technologies developed are dual-use and critical to DoD cost reduction goals. The delivery of mission enhancing, energy efficient, and environmentally sustainable facilities with scarce resources is a major challenge. Every dollar saved from infrastructure improvements is a dollar earned for mission-critical activities.

Within Airfields and Pavements, the goal is to reduce costs by 20 percent ($72 million per year) and extend the life (5 to 10 years) of the Army's military-unique roads, airfields, ports, and railroads by the year 2000. Potential payoff and transition opportunities include providing the U.S. military with a reliable launching platform to project mobile forces to support worldwide contingency conflicts. The Army pavements research leads the Nation. Civilian airports, 26 states, and many municipalities use the Army Airfields and Pavements Procedures.

For Survivability and Protective Structures (S&PS) the goal is to provide reliable and affordable structural hardening and camouflage, concealment and deception (CCD) that will increase survivability of facilities, equipment, and personnel against a broad spectrum of increasingly lethal modern weapon threats ranging from terrorist attack through regional conflicts and up to limited nuclear warfare. Lightweight, highly ductile, and high-strength materials with enhanced energy absorption will reduce hardening costs. Revised design and field manuals will provide greater survivability of fighting positions, fixed facilities, and retrofit of existing facilities to survive large length-to-diameter ratio penetrators and enhanced blast and thermal weapons.

The Sustainment Engineering subarea is structured to provide the civil engineering technologies required by Army for successful execution of strategic, operational, and tactical force projection, employment, and sustainment. Engineer troops will be able to support a deployed force in an austere theater with faster, lighter, less voluminous, and less manpower-intensive ways of executing mobility, countermobility, and general engineering missions. Transitions include Technical and Field Manuals, Guide Specifications, and the Army Facilities Components Systems.

Major Technical Challenges

Major technical challenges for the Conventional Facilities subareas are development of technologies for affordable automated condition assessment, integrated installation management tools, innovative revitalization technologies, and technologies to determine applicability and DoD-wide prioritization of energy conservation opportunities to reduce operations and maintenance costs. The major technology challenges for the S&PS subarea include innovative uses of lightweight, high strength, high ductility materials in protective construction and retrofit of existing structures to increase hardness at low cost and improve numerical models for accurate vulnerability assessments. The major challenges for Sustainment Engineering include methods to improve construction speed and reduce logistic requirements, methods to acquire and interpret data for infrastructure assessment, and methods to predict real-time sea-state forecasts and logistics over-the-shore throughput assessments.

Army research is currently working to overcome technological barriers in civil engineering by developing:

- Collaborative automated environment to optimize conventional facility life cycle costs by concurrent considerations of design, construction, operation, and maintenance.
- Rapidly installed breakwaters for attenuation of adverse sea-states for logistics-over-the-shore operations..
- Material, admixtures, dynamic 3-D models, and viscoelastic material responses for airfields and pavements..
- Criteria and materials for constructable survivability measures and simplified survivability (facilities, equipment, and troops) assessment capabilities for battlefield commanders.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Civil Engineering and Environmental Quality is shown in Table IV-L-1, below.

Table IV-L-1. Technical Objectives for Environmental Quality and Civil Engineering

Technology Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Environmental Quality (Conservation)	• Plant succession model for impact prediction and recovery potential. • Complete guidelines for 30% reduction in steambank erosion.	• Provide knowledge, approach, and tools to match land use and land capacity in selected ecoregions. • Models to simulate mission impacts on key protected species.	• 75% reduction in soil erosion on bases. • Risk-based ecosystem use models.
Environmental Quality (Cleanup)	• Advanced oxidation treatment for explosives in groundwater. • In-situ treatment of heavy metals. • Groundwater modeling system.	• Biotreatment of explosives in soils. • Fate and transport risk assessment model. • On-site assessment visualization.	• Remote multisensor UXO detection. • In-situ biotreatment of explosives in soil. • Supercritical water oxidation for destruction of waste.
Environmental Quality (Compliance)	• Guidance for intelligent application for Advanced Oxidation Processes (ADVOX) for munitions productions waste. • 25% reduction of VOCs in manufacturing energetics. • Nitrocellulose fines treatment.	• Treatment of advanced energetic materials used for propellants. • Advanced maintenance technology to reduce the cost of operating energetic manufacturing facility pollution control equipment.	• 90% reduction in VOC emissions from production facilities.
Environmental Quality (Pollution Prevention)	• ODS elimination for refrigerants, sealants, and degreasing cleaners. • Laser ignition to replace chemical ordnance to medium & large caliber ammunition (avoid toxins during manufacture and demil). • Improved tools/models for life cycle environmental analysis to assist weapon designers and PMs.	• Low VOC reformulated CARC paints. • Thermoplastic elastomer propellants elimination VOCs in manufacture. • Green Bullets (elimination of lead in primers and bullet cores). • Alternative Technologies to avoid open burn/open detonation of energetics (scrap/demil).	• Green Missile (lead elimination and no HCl emission). • Green Barrel (elimination of Hexavalent Chromium in waste water). • Halon 1301 replacement for ground tactical vehicles and aircraft engine protection (ODS problem solved). • Cleaner processes & products for energetics. • Aqueous processes for ceramics and composites.
Civil Engineering (Conventional Facilities)	• Addition of new building types into current version of Modular Design System to dramatically reduce delivery time of Army facilities. • Basic framework for an Integrated Installation Management System to reduce costs of O&M for Army installations.	• Reduce facilities acquisition, M&R costs by 15% of 1990. • Reduce energy consumption by 20% of 1985.	• Reduce facilities acquisition, M&R costs by 20% of 1990. • Reduce energy consumption by 30% of 1985.
Civil Engineering (Airfields and Pavements)	• New materials and design systems to increase pavement life at reduced costs. • Database development and interactive design systems for pavement prediction. • Fracture and durability model field validation. • Develop improved mixture design for quality control and quality assurance. • OCRs supported: CSS 17.	• Fundamental understanding and analytical capability to address all aspects of pavement response and behavior. • Methods and materials for rapid construction of operating surfaces. • Reduced life cycle costs and increased durability of DoD's pavement by 10% of FY93 cost. • OCRs supported: CSS 17.	• Provide criteria for APOE power projection platforms. • Criteria for airfield design and construction to support contingency operations world-wide. • DoD transportation systems designed with confidence levels of serviceability and performance. • 25% life cycle cost reduction of FY93 cost. • OCRs supported: CSS 17.

(Continued)

Table IV-L-1. Technical Objectives for Environmental Quality and Civil Engineering (Continued)

Technology Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Civil Engineering (Survivability and Protective Structures)	• Criteria for antipenetration systems to defeat heavy penetrators. • Procedures for retrofitting roofs and walls of existing facilities to provide protection from vehicle bombs. • Develop a family of protective systems using advanced materials and design procedures that will increase the survivability of troops (in fighting positions), weapon systems, materials, and equipment. • Quantify CCD signature-reduction techniques for materials used in fixed and relocatable assets. • OCRs supported: DBS 09; EEL 05, 10; DSA 05, 12, 13, 14; CSS 21; MTD 02, 19.	• PC-based design manual for hardened structures. • Constructible 5 to 6X conventional concrete strength at reduced cost for hardened facilities. Antipenetration systems to defeat very heavy robust penetrators. • Lightweight, high-strength composite framing elements for hardening structures. • Deployable protective packages for light forces. • Automated CCD design/analysis capability. • OCRs supported: DBS 09; EEL 05, 10; DSA 05, 12, 13, 14; CSS 21; MTD 02, 19.	• Vulnerability assessment model for retrofitting critical facilities to enhance survivability against advanced weapons. • Develop criteria for survivability of conventional facilities against entire spectrum of terrorist weapons. • Increase force survivability with 40% reduction in logistics burden. • Decrease probability of detection by 50% through advanced multispectral signature management techniques. • OCRs supported: DBS 09; EEL 05, 10; DSA 05, 12, 13, 14; CSS 21; MTD 02, 19.
Civil Engineering (Sustainment Engineering)	• Field demonstration of advanced materials for construction of operating surfaces. • Determine mechanical properties of snow and ice as construction materials. • Validate and document mobility data inference routines for all of the world's major climatic zones. • Demonstrate Obstacle Planning Software. • OCRs supported: CSS 17, 21; EEL 16, 29, 22; DBS 19; BC 03, 07, 23.	• Reduce construction time in soft soil by 35%. • First-generation theoretical mobility model. • Design for rapidly installed breakwater. • First Logistics Over-The-Shore Operational Simulator (LOTSOS). • Automated Bridge Classification System. • OCRs supported: CSS 17, 21; EEL 16, 19, 22; DBS 19; BC 03, 07, 23.	• Reduce horizontal construction time by 20%. • Reduce logistic requirements for engineer construction materials by 20%. • High-resolution mobility model for advanced vehicle platforms. • Gap/river crossing site selection procedures based on trafficability and crossability. • OCRs supported: CSS 17, 21; EEL 16, 19, 22; DBS 19; BC 03, 07, 23.

M. Battlespace Environments

1. Scope

The Battlespace Environments technology area encompasses the study, characterization, prediction, modeling, and simulation of the terrestrial, ocean, lower atmosphere, and space/upper atmosphere environments to understand their impact on personnel, platforms, sensors, and systems; to enable the development of tactics and doctrine to exploit that understanding; and to optimize the design of new systems.

Technology subareas for Battlespace Environments in the ASTMP are organized around a particular taxonomy that is specified in the Technology Area Plan prepared for the Office of the Secretary of Defense, Deputy Director for Research and Engineering. Two two technology subareas that apply to the ASTMP are the Terrestrial Environment and Lower Atmosphere Environment.

2. Rationale

Commanders at all levels must know how the environment will impact their operations as well as the operations of their adversary and use this knowledge for military advantage. Sensor and weapon system developers must also understand the environment's effects on system performance to optimize design effectiveness. This investment will provide the following improvements to future warfighting capabilities:

- An order of magnitude improvement in providing digital topographic data needed by the commander for optimized deployment, mobility, planning, and logistics support.
- High resolution weather forecasts for incisive decision making and enhanced operational capability in adverse weather; reduced weather-related damage, and fuel costs.
- Realistic representation of dynamic environment and terrain in simulations to permit more effective mission planning, rehearsal, and training.
- Realistic portrayal of the effects of the Battlespace Environments to reduce operational costs and reduce casualties.

3. Technology Subareas

a. Terrestrial Environment

Goals and Time Frames

The Terrestrial Environments subarea focuses on technology developments in the areas of cold regions research and topography. This work encompasses the study, characterization, and modeling of the physical phenomena, processes, interactions, and effects associated with terrain, its surface features, and the overlying atmosphere at scales of interest to ground combat forces.

Cold Regions engineering research focuses on the effects of snow and frozen ground on both materiel and winter operations. Topographic research focuses on better understanding the terrain through improved data generation, analysis, and modeling through the exploitation of multisensor data. Objectives in Terrestrial Environments technology development include the following:

- Millimeter wavelength (MMW) signature model to support system performance simulations in snow covered terrain (FY97).
- A dynamic terrain visualization capability to help create a virtual 3-D tactical environment to support training and mission planning during the Army's Task Force XXI exercise (capability is to be demonstrated and transitioned to Army simulation centers) (FY97).
- Model-generated passive/active infrared (IR) and background scenes of winter terrain for predicting sensor performance and design (FY02).
- Automated generation/update of topographic data for mission rehearsal and terrain visualization (FY02).
- Knowledge-based performance estimated for dual and multimode sensing systems operating in IR, MMW, and RF energy regimes over winter impacted terrain (FY07).
- Battlespace fly/walk through and automated terrain analysis capability (FY07).

- Dynamic Environment and Terrain (DET) implementation for use with computer-generated forces (FY07).

Cold Regions

The winter environment presents a severe challenge to not only the performance of materiel but also its operability. Snow and frozen ground dramatically alter the propagation of acoustic and seismic energy. The infrared and millimeter wavelength signature of terrain features change markedly with freezing and thawing. Icing may dramatically change aircraft performance and impact communications capability. The ability to quantify and model these processes and their effects are essential to system design, test and evaluation, mission planning, and war gaming. The Cold Regions technology effort objectives are to—

- Develop first principle models to predict the multispectral signatures of winter terrain surfaces and features for imaging sensor systems. The models will be structured to provide simulation capabilities for evaluating environmental constraints early in the development cycle of sensor systems.
- Determine procedures and equipment criteria enabling combat engineering operations to function effectively in winter conditions. This includes use of snow and frozen ground for expedient fortifications, facilities, roadways, and excavations; and operation of engineer equipment under winter conditions.
- Develop models of equipment and unit performance in winter conditions in sufficient detail to enable realistic simulation of these effects in interactive synthetic environments.

Major Technical Challenges

- Acoustic energy propagation is distinctly different in winter than in summer. The technical challenge is understanding the coupling that occurs between the complex air, snow, frozen-ground, and unfrozen-soil interfaces.
- IR, MMW, and radar interactions with winter terrain surfaces (i.e., snow, ice, and frozen soil).
- The impacts of low temperatures, snow, ice, frozen ground, and ice accumulation on the performance of materiel and equipment must be characterized to allow design of modifications, formulation of special techniques to overcome or minimize the constraints, and projection of the extent and duration of the impacts.

Development Milestones

(1) Transition signal inversion techniques for seismic-acoustic sensor self-calibration in a dynamic winter environment to Wide Area Mine (WAM) developers (FY97).

(2) Provide baseline data on the low temperature performance of composite materials to U.S. Army Tank Automotive Research Development and Engineering Center (FY97).

(3) Provide techniques, kits, and support systems to reduce low temperature degradation of engineer materiel performance to U.S. Army Engineer Center and School (FY98).

(4) Provide critical data for integrated winter operation tactical decision aids (TDAS) (FY99).

(5) Integrate seismic-acoustic sensor performance in a synthetic environment to optimize sensor performance (FY00).

(6) Transition model of the spatial variability of atmospheric icing to support communications and aerial operations TDAs to the U.S. Army Aviation Center and School and the U.S. Army Intelligence Center and School (FY00).

(7) Integrate physics-based multi-band dynamic environment models for prediction of sensor performance and optimizing sensor design (FY01).

Topography

Providing improved knowledge of the terrestrial environments through topography encompasses varied requirements. Efforts are needed to provide technology for rapid digital terrain data generation, terrain visualization, data/software standardization, terrain analysis, data management, and realistic mission rehearsal and training. The warfighter needs these types of capabilities to achieve superior knowledge of the battlefield through a common picture of the battlespace, to win the information war and thereby dominate maneuver.

Topographic science is the delineation and representation of positions and elevations of natural and man-made features. Science and technology efforts as shown in Figure IV-M-1 concentrate on remote sensing, spectral characterization/analysis, mapping, point positioning, land navigation, surveying, terrain/environmental analysis, and their effects on tactical operations, battlefield visualization, and modeling and simulation.

Objectives in topographic and geospatial information development include:

- Demonstration of advanced technologies for digital topographic data generation, update, and management, and for the implementation of dynamic terrain into mission planning and rehearsal capabilities and training systems.
- Use of knowledge-based techniques to improve terrain data exploitation for detecting and identifying features and changes and to predict terrain conditions to support cross-country movement, cover, concealment, site evaluation, and other combat decision models.
- Reduction of the time required to generate terrain and weather environments in distributed modeling and simulation to support training and mission planning and rehearsal.

Major Technical Challenges

- Identifying terrain features/targets automatically to respond within the enemy's decision cycle.
- Developing a total force positioning and navigational capability for the Army. Accurate fire and the ability to locate and navigate will be key to success on the obscured future battlefield.
- Promulgating standard verified and validate software to achieve joint interoperability goals.
- Generating terrain and weather environments in near real time for tactical operations and distributed modeling and simulation.

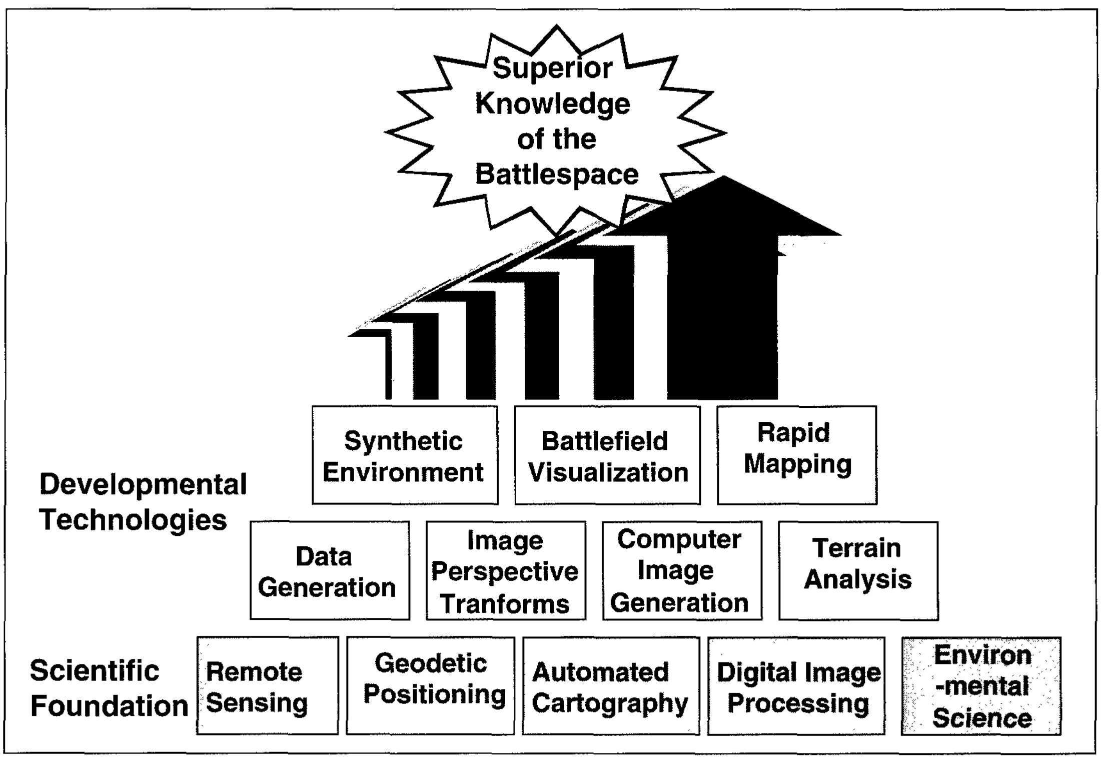
Development Milestones

(1) Transition correlated dynamic battlefield visualization capabilities (terrain and climate) for Distributed Interactive Simulation (DIS) to the Army (FY97).

(2) Demonstrate identification of natural and man-made materials using far infrared and laser induced fluorescence (FY97).

(3) Demonstrate the feasibility of passive fluorescence for identifying natural and man-made materials (FY98).

Figure IV-M-1. Topography Science and Technology



(4) Demonstrate multispectral imagery/hyperspectral imagery integration with digital terrain elevations for terrain feature extraction (FY98).

(5) Test initial field capability for automated feature attribution using multispectral imagery (FY98).

(6) Incorporate radar and hyperspectral imagery into DrawLand visualization software and transition software to Open GL architecture (FY98).

(7) Devise neural network image data classification system (FY98).

(8) Develop new methods for portraying terrain analysis product reliability (FY98).

(9) Transition techniques for filling terrain/climate data gaps through kriging/cokriging (FY98).

(10) Incorporate automated feature extraction techniques into the Digital Stereo Photogrammetric Workstation (FY99).

(11) Link 3D model and texture library to data base generation capability (FY99).

(12) Finalize development and testing of terrain/precipitation model (FY99).

(13) Investigate terrain data exploitation from high resolution spectral satellite systems (FY99).

(14) Complete Hypermedia Transfer Version of the Desert Field Guide (FY99).

(15) Complete study of micro electro-mechanical system (MEMS) for advanced positioning and navigation (FY00).

(16) Develop improved user interface to Defense Software Repository System (DSRS) Mapping, Charting, and Geodesy Domain (FY01).

(17) Refine terrain/climate models for modeling and simulation (FY01).

(18) Investigate capability for automated feature attribution based on terrain reasoning (FY01).

(19) Demonstrate visualization and command planning tools for urban data sets (FY01).

(20) Improve terrain data inferencing methodologies (FY02).

(21) Demonstrate a spectrally enhanced multisensor exploitation capability (FY02).

(22) Demonstrate linkages of image-based visualization systems with feature attribute data bases (FY03).

b. Lower Atmosphere Environment

Goals

The Army's role in the Lower Atmosphere Environment subarea encompasses three technology efforts: Current Battlespace Weather, Predicted Battlespace Weather, and Decision Aids. One particular Service will assume the lead in specific research and development areas, and that work will be adapted by other Services. The Army's efforts in these areas are in accordance with and keyed to objectives laid out in the TAP.

The goal of the Current Battlespace Weather thrust is to provide the ability to determine weather information for a battle-size area anywhere in the world. This is accomplished through direct or remote sensing of atmospheric parameters. The Predicted Battlespace Weather thrust concentrates on methods to predict atmospheric conditions over a battle-size area for any time from the present up to 2 weeks in the future. These predictions use analysis of any available data, as well as meteorological modeling. The goal of the Decision Aid thrust is to provide information to warfighters on the effects of the current and predicted atmospheric conditions. This involves assimilating and disseminating weather information and threshold values for all weather sensitive systems in order to produce tailored decision aids.

Successful accomplishment of these goals will provide the Army with the capability to Own the Weather, using knowledge of the lower atmosphere environment and its effects to gain an advantage on the battlefield.

Current Battlespace Weather

Accurate and timely weather and atmospheric information over critical parts of the battlespace will provide future higher resolution forecast models with the initialization data to increase their accuracy. Combining the new capabilities of remote sensing systems operating from ground, air, and space platforms with covert, small signature, in situ sensor platforms will result in new real-time data of the battlespace and target area meteorology environment. The changing role of U.S. forces into a reactive force deployed to global small-scale conflicts requires that this information be available on extremely short notice throughout the world. With the evolving capability of high resolution battlespace forecast models, as discussed below, this data will provide the critical initialization information and confirm the model predictions for commander confidence of planning decisions. Basic research focuses on the measurement of small-scale phenomena in the planetary boundary layer, including aerosols along with weather parameters. Objectives include the following:

- Extract battlespace weather and atmospheric information from satellite active remote sensors. Provide data from ground to space with four times the accuracy of current passive sensors, covering 40 percent of the global surface in under 4 hours.
- Automate data retrieval from tactical weapon platforms. Increase battlespace data collections by a factor of five over current sensors.
- Provide seamless data distribution between Services and tactical areas. Common, joint data collection and communication allows all Services to share data in realtime for a consistent, accurate battlespace "nowcast" picture.
- Develop ground-based remote sensors which operate "on the run" to support future force mobility. Provide data 87 percent faster than today's technology.
- Better understand the usefulness of sensor development and applications and the use of field data sets to understand complex physical processes such as surface layer interactions to support theater operations.
- Provide quantitative assessments of the linear and nonlinear characteristics of natural and man-made battlefield aerosols that impact on visible through millimeter wave propagation and aerosol detection.
- Develop advanced laboratory measurement techniques and instrumentation as tools for aerosol microphysics diagnostics and for the detection and identification of chemical/biological warfare agents.
- Develop aerosol and gaseous information sufficient to model quantitatively atmospheric limitations on military systems that rely on using radiation (UV, visible, IR, and millimeter wave) for detection, imaging, and identification.
- Develop and test ground-based and satellite remote sensors for battlefield atmospheric characterization of the dynamic and thermodynamic properties of aerosol and gases, such as temperature, density, wind fields, water vapor, and chemical/biological warfare agents.

Major Technical Challenges

- Develop remote sensor concepts and software that provide tactical data for battlefield meteorological models, precision strike weapons, and general real-time situational awareness on the battlefield.
- Develop measurement systems that resolve the microscale dynamical structures for the verification of atmospheric models operating at these scales. Technical barriers for basic research involve the investigation and explanation of previously unobservable atmospheric phenomena occurring at these scales, such as the convective boundary layer, gravity waves, and shear instabilities.
- Determine the characteristics of aerosols, their dynamic properties in the atmospheric medium, and their optical properties over all spectral bands of military interest and develop the instrumentation that permits the detection and analysis of aerosols.

Development Milestones

(1) Demonstrate, at the Army Field Artillery School, Ft. Sill, Oklahoma, a downsized prototype atmospheric Profiler, trailer mounted, with an integrated Radio Acoustic Sounding System (RASS), capable of being towed by a HMMWV. Make measurements in one-eighth the time required by the Mobile Measurement Set (MMS), and reduce by 33 percent the number of vehicles and soldiers required (FY97).

(2) Complete development of neural net software for retrieving met satellite temperature soundings, and couple with an improved Profiler radiometer to eliminate the need for the RASS. Eliminate the requirement for the Profiler RASS, making it possible for a Profiler antenna to fit on top of a Single Integrated Command Post (SICP) shelter (FY98).

(3) Complete development of neural net software for direct retrieval of wind speed and direction from met satellite radiance data. Improve the accuracy of met satellite measured winds by 50 percent (FY99).

(4) Determine limits of laser-induced fluorescence for remote sensing and identification of chemical/biological aerosols under realistic battlefield conditions, and provide results to ERDEC (FY99).

Predicted Battlespace Weather

Relying on the Navy and Air Force large-scale, long-term prediction models allows the Army to concentrate on resolving the smallest battlespace scales, below one kilometer in space and one hour in time. As advances in the regional and theater scale models allows reliable forecasts beyond 10 days, the Army will reduce the space and time scales to 100 meters/1 minute and below to resolve the boundary layer processes that influence the propagation of acoustic and EO energy, and the motion and dilution of chemical and biological agents on the battlefield. Running as nested applications below the large-scale models, the battlespace model will provide the spatial and temporal data that fills in the scales provided by the larger models. Basic research focuses on transport and diffusion modeling and optical effects of the atmosphere on propagation through turbulence. Specific objectives include the following:

- Link battlescale forecast models with gas/aerosol transport and diffusion models to provide 4-D predictions of chemical and biological agent threats on the future battlefield. Increase accuracy of spatial forecast by 50 percent and concentrations by 60 percent.
- Optimize environmental prediction models to allow operation on virtually all tactical weapon systems, from the future soldier to artillery and missile systems. Provide more accurate and timely data for platform-specific decision aids.
- Develop a stand-alone analysis system that will emphasize key weather elements and weather phenomena for important decision making factors, which can serve all Services for the purpose of improving nowcasting, forecast guidance products, and, potentially, the analysis in the mesoscale numerical weather prediction system.
- Build a mesoscale numerical weather prediction system appropriate for battlescale applications including the boundary layer. The system should be capable of assimilating a wide range of data over complex inland and coastal terrain and accounting for improved cloud and aerosol treatment in the model physics, and it should include physical process oriented forecast models.
- Develop descriptions of the dynamic flow interactions with highly complex terrain, vegetation, and structures that can run on a variety of computer systems, from battlefield workstations to supercomputers.
- Improve modeling of transport and diffusion (T&D) of gases, particulates, and pollutant plumes essential to the DoD's chemical and biological warfare R&D programs. Couple T&D models to mesoscale NW models to forecast aerosol dispersion and concentration.
- Understand and model the propagation of acoustic and short wavelength electromagnetic radiation in the atmosphere under natural and battle induced conditions.
- Develop electro-optical (EO) propagation and target background signature models.

Major Technical Challenges

- The computational speed and memory/storage required to resolve the mesoscale phenomena and to represent and predict mesoscale physical processes is extraordinary. Transport and Diffusion (T&D) of gases and particulates require treatments more sophisticated than traditional Gaussian plume models to represent the turbulent, chaotic nature of atmospheric motions. Technical barriers for basic research involve the development of probability density function (PDF) solutions in order to predict the concentration fluctuations, a critical issue for soldier system exposure, and the development of improved nonlinear solutions for the Navier Stokes equations that describe the physical process of T&D.
- The flow of the atmosphere around and through vegetative canopies and through urban "canopies" plays a critical role in the use of countermeasure aerosols and for chemical and biological defense. Models of such flow

must be available for operation on tactical systems.

Development Milestones

(1) Demonstrate in Task Force XXI a 24-hour Battlescale Forecast Model (BFM) using client/server connectivity to the Army Battle Command System (ABCS). Reduce forecast errors by 35 percent for winds, temperature, pressure, and humidity while running on Army Common Hardware computers (FY97).

(2) Deliver to the Integrated Meteorological System (IMETS) a non-hydrostatic moisture microphysics BFM for clouds and precipitation forecasts. Improve adverse weather forecasts by 40 percent while running on Army tactical computers (FY99).

Decision Aids

Mission planning and weapon selection on a future highly mobile, extremely lethal battlefield will require the commander to have available the best possible information on the impact of the weather and atmosphere on the mission objective. Decision cycles will shorten, forces will be more dispersed and independent, and thus future decision aids must operate on the tactical platforms, using all the data the sensors and model provide and providing the output in the most effective assimilation format. Weather impact decision aids will allow the commander to employ the weather as a combat multiplier. Specific objectives include the following:

- Develop integrated weather/atmospheric data, broad spectrum propagation models and advanced visualization methods, to provide 3-D visualized decision aids showing graphical depictions of atmospheric impacts on mission plans and weapon use for current and future battlefields.

- Automate mission planning tools based on detailed knowledge of environmental impacts, to optimize the commander's planning and decision-making ability. Improve the required mission output, as defined by the commander, by 30 percent over current methods.

- Integrate atmospheric and background models with target prediction models to ensure that atmospheric effects are included in the assessment of weapon system performance, survivability, and vulnerability.

- Develop propagation assessment systems with associated environmental decision aids, simulation and visualization capabilities, and sensitivity analyses.

- Develop environmental decision aids for operational and tactical levels of war planning and training which give the effects and impacts of weather and battle-induced atmospheres on U.S., allied, and threat unit functions, systems, subsystems, sensors, and personnel.

- Develop real-time weather and environmental effects models (obscurants, illumination levels, EO, and acoustic propagation) to provide common, unified weather effects, features, and representations leading to improved battlescale forecasting for simulation, training, doctrine, and C3 systems that are compatible for all Services.

Major Technical Challenges

- Battlespace prediction models and parameterization methods for boundary layer physical processes will crucially depend on in-theater data assimilation methods that fully exploit all sources of weather observations from remote and in situ platforms. Development of robust and flexible procedures, based as field programs, to adapt to the available data options in real time will be needed.

- As the observation data from various sensors and platforms increase and the fusion and prediction are highly synergized, quality control is essential to ensure the accurate description of the state of the atmosphere.

Development Milestones

(1) Demonstrate integrated EO/acoustic/gas/biological agent propagation with tactical weather data and DIS visualization tools for mission planning at Division Task Force XXI. Improve multi-component mission planning by 40 percent over current binary decision aid technology; improve information assimilation by 60 percent over 2-D map decision aid displays (FY98).

(2) Demonstrate decision aids that display 3-D sound levels over terrain (FY98).

(3) Demonstrate satellite remote sensing of battlespace environments and tactical use of such information in operational decision aids to CECOM (FY01).

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Battlespace Environments is shown in Table IV-M-1, below.

Table IV-M-1. Technical Objectives for Battlespace Environments

Technology Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Cold Regions	• Enhance capability of IR, MMW smart weapons in dynamic winter environment. • Provide physics-based dynamic winter effects on terrain and systems for inclusion into the synthetic battlefield. • Minimize the degrading effects of winter and associated cold environments on the target tracking and identification capabilities of seismic/acoustic based sensor systems. • Develop remote icing accumulation detection method to support winter operations. • Develop low temperature/thermal cycling performance criteria for composite materials. • OCRs supported: DSA 03, 09, 12, 14; TRD 01(3); DBS 04A; BC 01; EEL 04, 07, 13, 16, 18; MTD 03.	• Enhance physics-based 3-D representation of complex terrain and weather conditions with modeling architectures that will allow practical application within DIS networks. • Dynamic Environment and Terrain (DET) Simulation for Cold Regions. • Develop methods to predict and alleviate the effects of ice accretion on military equipment to include aviation, communications and sensors. • Validate low temperature/ thermal cycling performance criteria for new composite materials for Army applications. • OCRs supported: DSA 03, 09, 12, 14; BC 01; MTD 01, 02, 19; EEL 04, 07, 13; TRD 01(3); MTD 03; EEL 16, 18.	• Enhance performance of smart and brilliant weapons and surveillance systems development to distinguish target signatures within complex winter backgrounds. • OCRs supported: MTD 01, 02, 19; EEL 04, 07, 13, 16; TRD 01(3); BC 01.
Topography	• Demonstrate objective capability for dynamic terrain representation. • Develop a capability to identify natural and man-made materials using hyperspectral data. • Demonstrate a capability to rapidly generate digital terrain data from IFSAR. • OCRs supported: BC 07; DBS 22; DSA 12; EEL 05; MTD 02, 16; TRD 01.	• Provide standardized digital topographic applications software to the Army Reuse Center. • Demonstrate phenomenology, dynamic terrain representations and improved terrain for Computer Generated Forces within the advanced distributed simulation architecture of Synthetic Theater of War (STOW) 97. • Field a capability for automated generation and update of topographic data. • Develop automated spectral signature extraction of terrain features from image cubes. • Provide multiscale/multiproduct terrain visualization software. • OCRs supported: BC 01, 05; DBS 19; DSA 07; EEL 10, 22; MTD 17, 19; TDS 02, 05.	• Investigate emerging satellite data for enhanced terrain feature generation and direct 3-D imaging. • Develop dynamic atmospheric modeling. • Investigate and develop capability for fully automated real-time terrain visualization. • OCRs supported: BC 01, 05; DBS 11, 19; DSA 07; MTD 16, 17; EEL 12, 22.
Current Battlespace Weather	Develop prototype mobile Profiler that couples satellite and ground-based atmospheric soundings. • OCRs supported: DBS 10, 11, 19; DSA 01, 02, 12.	• Profiler downsized for mounting on top of HMMWV shelter. • Develop capability to identify biowarfare agents with portable point detector. • OCRs supported: DBS 10, 11, 19; DSA 01, 02, 17; MTD 07, 16.	• Profiler replaced met balloon on battlefield. • OCRs supported: DBS 19; DSA 17.

(Continued)

Table IV-M-1. Technical Objectives for Battlespace Environments (Continued)

Technology Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Predicted Battlespace Weather	• 24-hr Battlescale Forecast Model (BFM) as server for weather effects clients on Army Battle Command System. • Computer Assisted Artillery Meteorology (CAAM) Time Space Weighted Model and BFM on Met Measuring Set for increased artillery accuracy. • Demonstrate ability to determine wind flow over complex terrain and land use features such as vegetative canopies and built-up areas. • Target and scene shadow effects incorporated into target acquisition model. • OCRs supported: BC 07; DBS 11; DSA 01, 17; MTD 01, 16.	• 48-hr BFM with higher resolution and increased accuracy. • BFM moved to indirect fire control computer to increase artillery accuracy. • Incorporate terrain and weather effects into operational chem/bio hazards prediction model. • OCRs supported: BC 03, 07, 23; DBS 10, 11, 19; DSA 01, 02, 17; MTD 07, 16.	• Horizontal/seamless integration of automatic battlescale weather forecasting throughout Army Battle Command System. • 3-D acoustic propagation model for 20 km ranges. • OCRs supported: BC 03, 07; DSA 17.
Decision Aids	• Realistic weather from BFM and background scenes integrated into DIS. • Weather effects decision aids integrated into Army Battle Command System. • Client/Server architecture demonstrated during Brigade TFXXI. • Integrate smoke/obscurants into 3-D DIS. • Demonstrate visualization of environmental effects for simulations. • OCRs supported: BC 03, 04, 05, 07, 23; DBS 11, 19; MTD 15, 17, 20; EEL 21; DSA 17; TRD 01.	• Integrated Weather Effects Decision Aid in Army Common Software toolkit as reuse software. • Develop decision aids that display 3-D sound levels over complex terrain. • Battlefield acoustic/seismic simulator. • OCRs supported: BC 03, 04, 07, 23; DBS 11, 19; MTD 16, 20; TRD 01.	• Battlefield atmospherics for advanced DIS. • Physical environment representation for real-time fly-through Advanced DIS. • OCRs supported: BC 07, 23; DBS 19; EEL 21; MTD 20; TRD 01, 05.

N. Human-Systems Interface (HSI)

1. Scope

Army requirements stemming from soldier, mission, system, and environmental heterogeneity must contend with boundary conditions not encountered by other Services or in the private sector. HSI technologies leverage and extend the capabilities of the Army's warfighters and maintainers to ensure that fielded systems will exploit the fullest potential of the warfighting team, irrespective of gender, mission, or environment. HSI technologies rest on a sound, scientific basis to ensure that the boundaries encountered are open frontiers, not barriers to effectiveness. To best address resulting requirements, Army HSI technologies are organized into four subareas: Information Management and Display develops methods and media to process and deliver task-critical information to individuals, teams, and organizations. Performance Aiding technologies minimize human error, overcome sensory and physical limitations, and improve mission performance. System Supportability develops and demonstrates specialized technologies to improve the functional operation and logistical support of defense weapon and automated information systems. Design Integration develops technology to integrate crew members with weapon system hardware and software to ensure maximum mission effectiveness, survivability, and supportability. This section reflects the tri-Service Reliance Technology Area Plan (TAP) for HSI. In the interest of leveraging internal resources, HSI research and resulting technologies are horizontally integrated across subareas to the fullest extent possible (see Technology Roadmap).

2. Rationale

The most important warfighting system is the individual soldier and the immediate functional unit, well equipped with modern weaponry and equipment. The soldier-system interface—that link between the human and electronic, mechanical and other physical devices and aids, in real and simulated environments and events—is often subject to errors in perception, cognition, situational awareness, and decision making. HSI success is also predicated on managing the effects of fatigue, physical overload, and stress. From the individual soldier's weapon through complex team-operated systems, HSI research is essential to meeting JCS warfighting needs in emerging quick-reaction, information-intensive, operational environments. With this emergence, the human has become, simultaneously, the enabling component and the limiting factor in military operations. Today's environment requires minimizing both soldier-system costs and exposure to combat risks. To this end, HSI technologies focus on enabling smart, systematic downsizing of both equipment and personnel ranks, while leaping ahead in battlefield mission effectiveness to provide quick, decisive victory.

3. Technology Subareas

a. Information Management and Display (IMD)

Goals and Time Frames

The primary goal of IMD is to maximize information throughput from available and emerging sensors, processors, and displays to warfighters, including commanders. IMD research develops supportable, time-sensitive information handling and display components which serve as visual and auditory HSI for both weapons and support systems. A second goal is development of simulation interfaces of sufficient fidelity to (1) enhance mission planning and (2) permit diagnostic examination of emerging technologies and concepts, as if they were mature enough for fielding. Supporting efforts include model development. Maturation of intelligence-filter visualization for C3I (see STO IV.N.01, Intelligent User Interfaces) is projected for 1997. By 1998, intervehicular dispersed decision-making equipment and concepts will be field tested. By 2004, 3-D video and audio "immersion" displays will dramatically enhance situational awareness, survivability, and effectiveness while reducing potential fratricide. By 2010, 3-D volumetric and immersion devices, as well as cost- and workload-reducing benefits of voice-, eye-, brain-, and touch-operated interfaces will have tri-Service commonality.

Major Technical Challenges

Too little time and too many information sources, ranging from low to high conditions of uncertainty, threaten to overwhelm the human capacity to monitor available data and to successfully and interactively query and manage multiple data sources. Specific challenges are as the follows:

- Improve alerting, warning, and IFF systems for tactical and operational workstations.
- Minimize exposure of personnel to hazardous environments.
- Fuse visual, auditory, speech recognition, and tactile display information for real, teleoperation, and simulator systems.
- Develop individual soldier-level virtual reality displays (auditory, visual, kinematic).
- Develop Decision Aids which assemble key elements of information, display complex data rapidly, speed decisions, and improve their quality.
- Toward supportability, standardize advanced components, algorithms and methods across weapons and Services.

b. Performance Aiding

Goals and Timeframes

These technologies will enable soldiers to operate well beyond normal mental, physical, and perceptual capabilities and will enhance system performance in stressful, hazardous, time-constrained, inhospitable, and remote environments. Time-phased goals are as follows: Through 1997, conduct field evaluations for computer-aided crisis management decision support; conduct field evaluations of unmanned robotic command vehicles; integrate and test mobile manipulator platform control; conduct ergonomic task analyses to redesign tasks and equipment to lower physical requirements. By 1998, enhance small arms shooter accuracy, reliability, and recoil management; demonstrate concepts for battlefield synchronization; establish tactile feedback database for a range of simulation devices; demonstrate "on-the-move" collaborative techniques. By 1999, develop and evaluate algorithms for real-time tactical decision making; evaluate collaborative visualization for distributed problem solving.

Major Technical Challenges

Technical challenges are varied.

- For decision aiding, including collaborative aiding: Understand the mechanisms of complex decision making and team collaboration, i.e., workload, uncertainty, individual and coordination strategies, and real-time structural reconfiguration.
- For physical and perceptual aiding, including teleoperations: Develop user-based, computer-assisted map storage, retrieval, and reading. Provide aids which, combined with electro-optical sensors, provide textural, shape, color and stereo effects information. Provide small-arms "inertial reticle" level of aiming accuracy.
- For distributed collaboration: Understand the mechanisms of complex team collaboration; devise reliable, diagnostic measures for team performance in distributed group environments.
- Umbrella challenge(s): (a) Integrate these aids in support of complex programs such as the Rotorcraft Pilot's Associate. (b) Develop standardized, diagnostic, field-operational metrics for use by Battle Labs, Army Digitization Office, and RDECs in defining and evaluating integrated solider information-system performance on the digitized battlefield (STO IV.N.04, Performance-Based Metrics for the Digitized Battlefield).

c. System Supportability

Goals and Timeframes

The goal of this subarea is to improve affordability and availability by improving system operability, maintainability, and logistical supply while reducing life-cycle support costs. The Army must produce technology to provide early estimates of human factors, manpower, personnel and training (HMPT), and associated human performance requirements and costs for the HSI, and to enfold those requirements in acquisition and design. This area directly complements and integrates HSI efforts in seeking a scientific understanding of the factors that can enhance or diminish overall human-system performance. By the end of 1997, task analysis models to predict maintainer performance will be ready for validation. The set of computerized human factors integration tools

(IMPRINT) will, by 1999, provide simulation-based determination of training and system supportability concepts, requirements, and resources. By the close of 1999, these techniques will be robust enough to permit valid quantitative trade-off analyses among HMPT variables and design options; this will allow decision makers to readily examine variations in system performance as a function of such soldier elements as manpower levels, personnel staffing, and training investment. These analytical models will be derived from human performance data. The far term will provide real-time operational system supportability and operational readiness assessment capability.

Major Technical Challenges

A major issue in defense system modernization concerns the increasing complexity of weapon systems which are being developed and the need to support those systems with personnel who can effectively operate and maintain them. While such systems can gain in technical complexity, the human cannot adapt as quickly as the changes require. Training and system complexity must be optimized to meet soldier needs. R&D is needed to map out the edges of the envelope concerning attention saturation, excessive mental workload, manpower utilization, and the HSI's optimization of BIT/BITE or embedded training technologies. That is, it must be determined how best to balance soldier resources and requirements with emerging technologies in order to maintain full military readiness, availability, sustainability, and effectiveness.

d. Design Integration

Goals and Timeframes

The pace, complexity, and precision of the future joint warfighting environment demand weapons systems that fully exploit the human contribution. Effective design tools, HSI models and databases, and performance metrics, usable throughout the RDT&E process, are required to produce a fully integrated crew-weapon or information system. This is accomplished by inserting human-system performance and cost variables into the system design process. Both a national and international technology capability must be developed to enable human performance assessment and modeling, and to provide tools and methods for enhancing physical accommodation, human error and reliability assessment, and soldier or crew "station" design and testing, all within the synergistic context of weapon system engineering. There is collaboration with the Army's MANPRINT program and this subarea. Technology timeframes: In 1997, validate a computer simulation model of military intelligence production; demonstrate a reconfigurable cockpit simulator; and validate Crewman's Associate design on a simulator. By the end of 1997, develop a database to support analysis of the Soldier as a System. By 1998, in coordination with the Battle Lab, quantify soldier performance for Force XXI; demonstrate a mission reconfigurable crew station. By 1999, develop full-body human CAD templates (see STO IV.N.03, Human Figure Performance Model). By 2000, implement dynamic clothing in the JACK model; fully integrate GASCO into the MIDAS tools suite. Finalize standardized individual soldier performance measures for use on the twin U.S.-France outdoor soldier performance analysis research course. By 2005, develop the data base to support international soldier modernization. By 2010, wear the HSI "cockpit" to the platform; complete multi-modal interactive sensory displays.

Major Technical Challenges

While an enormous amount of human performance data has been collected over the past 50 years, it is largely inaccessible to the engineering design community. Consequently, HSI has been performed relatively late in the design cycle, and evaluations, until quite recently, have been conducted only with costly physical prototypes. The most critical challenges include:

- The magnitude of existing and emerging anthropometric and accommodation data ases, nationally and internationally.
- The complexity of simulating and quantifying the effects of battlefield conditions on human mobility, sustainability, and performance.
- The diverse and fragmented technical disciplines that must be integrated to produce these design technologies.
- The lack of industry or government standards and methodologies for HSI and crew system integration.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Human System Interfaces is shown at Table IV-N-1, below.

Table IV-N-1. Technical Objectives for Human-Systems Interface (HSI)*

Technical Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Information Management and Display (IMD)	• Context-sensitive intelligent interface. • Implement cognitive decision aiding tools into simulation use (PA). • Develop algorithms to support commanders for operations on the move. • Refinement of "audio icon" and integration to simulation platform. • OCRs supported: BC 01, 02, 03, 05; CSS 01, 02, 18; DBS 03, 09; MTD 02, 14, 16, 18, 20; TRD 01 (2,3), 02 (1,2), 03 (2), 05 (2).	• Indicators and warnings for dismounted soldiers. • Distributed Interactive Simulation for the individual soldier. • Command-on-the-move controls and layouts. • Development of information engineering guidelines for information rich environments. • Develop flight, other symbologies for enhancing helmet mounted displays (HMD). • OCRs supported: BC 01, 02, 03, 05; CSS 01, 02, 18; MTD 02, 14, 16, 18, 20; TRD 01 (2-3), 02 (1,2), 03 (2), 05 (2).	• Multi-modal interactive sensory displays. • Individual soldier "SIMNET" (I-PORT). • 3-D audio and video immersion displays. • 3-D volumetric and immersion devices. • Tri-service commonality on HSI (PA, SS, DI). • Develop human factors design guide for HMD. • OCRs supported: BC 01, 02, 03, 05; CSS 01, 02, 18; DBS 03, 09; MTD 02, 14, 16, 18, 20; TRD 01 (2,3), 02 (1,2), 03 (2), 05 (2).
Performance Aiding (PA)	• Develop database of soldier clothing and equipment compatibility information (DI). • Refine assessment techniques for national and international (joint coalition force) soldier modernization programs (SS). • Establish reach, vision, strength criteria for female crew. • Develop prognostic model of intelligence production and fusion. • Develop "precursor" performance metrics and markers for team unit. • OCRs supported: BC 11, 13, 25; CSS 10, 14, 17; DBS 01A, 02A, 03, 09, 10, 14, 16, 20, 23; EEL 11, 12.	• Aiming accuracy, recoil mitigation, and indirect fire for small arms. • Strength augmentation and sensory enhancement. • Ergonomic design model for reducing soldier lift, carry, push, pull loads. • Performance related model of injury-stress relationship. • For teleoperations, development of aids to provide textural and distance information, and to minimize attentional fixation. • OCRs supported: BC 11, 13, 25; CSS 10, 14, 17; DBS 01A, 02A, 03, 09, 10, 14, 16, 20, 23; EEL 11, 12.	• Integrate personal performance enhancement of hardware and weapons (DI). • Links to AI attributes, neural networks. • Release graphic soldier model with reach, vision, and strength database. • OCRs supported: BC 11, 13, 25; CSS 10, 14, 17; DBS 01A, 02A, 03, 09, 10, 14, 16, 20, 23; EEL 11, 12.
System Supportability (SS)	• Human resource cost models relative to IEW, C2V. • Integrate models and data bases for HMPT. • OCRs supported: BC 03, 11; CSS 14, 18, 24; MTD 18, 20.	• CAFT models for soldier systems. • Mission reconfigurable crew station (DI). • Teleoperation crew station layout (DI). • Full integration of GASCO into the MIDAS tool suite. • Simulation-based determination of training and system support concepts, requirements, resources. • OCRs supported: BC 03, 11; CSS 14, 18, 24; MTD 18, 20.	• Integrated real-time and predictive system supportability and operational readiness assessment capability. • OCRs supported: BC 03, 11; CSS 14, 18, 24; MTD 18, 20.
Design Integration (DI)	• Task performance models for expanded mission areas (C2, maintenance, etc.). • Evaluation of alternative system designs at notional system stage (SS). • OCRs supported: BC 11, 13,	• Database matrix for soldier-system technologies for future system design evaluation. • HMPT analysis tradeoff tool for system redesign options (SS). • OCRs supported: BC 11, 13, 25; EEL 11, 12; MTD 02, 18, 20.	• Full, synergistic, analysis capability from concept through prototype and from detailed interface specifications through force-on-force simulations (SS). • Diagnostic links to system design, design costs, tactics, training. • OCRs supported: BC 11, 13, 25; EEL 11, 12; MTD 02, 18, 20

*( ) Denote secondary areas of categorization

O. Manpower, Personnel, and Training

1. Scope

The DoD Manpower, Personnel, and Training program seeks to maximize human military performance. Army science and technology investments in manpower and personnel technology address recruitment, selection, classification, and assignment of people to military jobs. It seeks to reduce the attrition of high quality personnel, supports the development of managers and leaders, and helps leadership to predict and measure the consequences of policy decisions. Army Science and Technology investments in training technology improve the effectiveness of individual and collective training, enhance military training systems, and provide more cost-effective opportunities for skill practice and mission rehearsal. Manpower, personnel, and training technologies provide efficiencies in the operation and maintenance of both current and future systems and result in increased readiness of our warfighting forces.

2. Rationale

The U.S. Army Posture Statement (FY96) states: "To leverage [emerging digital] technology to its highest potential, the sophisticated systems of the future will demand a soldier who is intelligent, physically fit, educated, highly motivated, and well trained. Force XXI will leverage the abilities of the best soldiers in the Army's history through the use of simulations and simulator-enhanced training. As they have been since the founding of America's Army, soldiers will be the most important element of Force XXI." Intelligent selection, classification, retention, and organization of quality soldiers are necessary to maintain a stable, disciplined, well-trained fighting force. Effective individual and unit collective training strategies must be developed to meet the Army's changing roles and missions in the face of decreasing resources.

Significant advances in distributed interactive simulation (DIS) and virtual reality technologies permit the development of synthetic environments which can be used to provide realistic combat training. As reflected in the Army Modernization Plan, "Advances in the behavioral sciences are required to provide empirically-based training strategies that lead to the most cost-effective use of new training technologies."

3. Technology Subareas

Under Project Reliance the Army manpower, personnel, and training community has the DoD lead for research on:

- Human Resources
- Leader Development
- Unit Collective Training
- Rotary Wing Training
- Land Warfare Training

Research and technical challenges in these areas are described below.

a. Manpower and Personnel

Goals and Time Frames

Selection and Classification. Improved aptitude testing, coupled with more sophisticated assignment systems, reduces training time and increases quality of performance. Research to modernize and improve the Army's selection and classification capability focuses on developing methods to measure performance-related aptitudes (FY97); identifying Force XXI NCO job requirements (FY98); and developing improved methods for assessing individual attributes and performance (FY99).

Human Resources Development. This program provides products and methodologies to improve leadership in complex and ambiguous situations, support efficient career development, and improve support for soldiers and their families. Research includes investigating personnel issues related to the Reserve Component deployment in the Multinational Force and Observers (MFO) Sinai peacekeeping mission and active duty and RC deployments for Operation Joint Endeavor in Bosnia. Areas addressed include leadership, morale, training, family issues, and soldier health and well-being, as well as the impact of stability operations on commitment and retention (FY97).

Life course theory is being applied to investigate the current and long-term effects of combat, organizational, and mission changes (e.g., downsizing, peace operations, ethnic diversity, gender integration) on career commitment and development in Army leaders (FY98).

Leader Development. This research focuses on understanding, evaluating, and determining the behaviors required for effective leadership. This will be accomplished through the collection and analysis of descriptive, experiential, and empirical data tracking the careers of officer candidates and officers (FY98). In support of the Battle Command Battle Lab operational capability requirements, new technologies and interventions will be developed for improving commander and command group decision-making skills (FY98).

Major Technical Challenges

- Develop new selection techniques which cover a wider range of human abilities, as well as relate aptitude tests to performance on the (simulated) battlefield.
- Develop techniques for DoD and Army decision makers, unit commanders, soldiers, and their families to effectively adapt to organizational change.
- Identify characteristics of the most effective military leaders and develop methodologies for assessing, developing, and retaining quality leaders.

b. Training

Goals and Time Frames

Unit Collective Training. The effectiveness of synthetic and DIS environments rests in large measure on the training strategies, performance measurement techniques, and performance feedback methods employed. Research goals are to develop training packages and evaluation techniques to support emerging Force XXI digital capabilities; specify the required simulation capabilities and the effective mix of live exercises with new and existing training aids, devices, simulators, and simulations (FY98); determine training needs for mission planning and mission rehearsal tasks (FY98); and develop measures to assess performance and provide feedback for DIS systems, such as the Close Combat Tactical Trainer (FY98). In support of the Mounted Battlespace Battle Lab, develop training and evaluation technologies that will prepare operators and commanders to take maximum advantage of evolving digital command, control, and communication systems (FY01). Much of the research will be conducted in conjunction with the Battle Lab's advanced warfighting experiments.

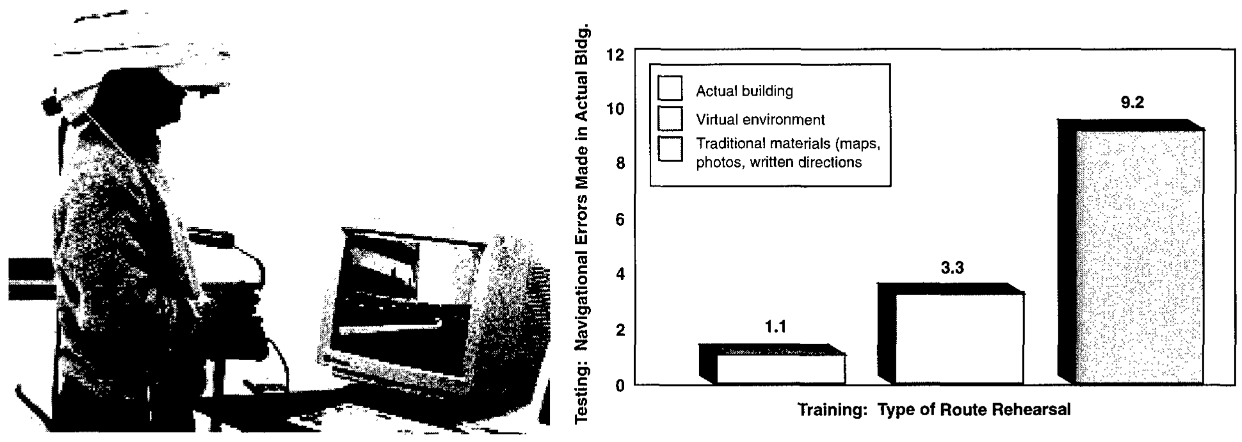
Rotary Wing Training. This research uses a state-of-the-art Simulator Training Research Advanced Testbed for Aviation (STRATA) to evaluate all significant parameters of simulator design to determine their contribution to the development and retention of aviation skills. Goals include developing display resolution requirements for flight simulator-based task training (FY97), determining fidelity requirements for collective tasks in networked systems for aviation unit training (FY98), and developing aviation task training requirements for helmet mounted displays (FY98).

Land Warfare Training. Research is directed at developing guidelines for cost-effective training strategies for individual and unit training for mounted and dismounted operations, including active and reserve component units, and for stability operations. Goals are to evaluate a prototype staff training package using Force XXI command brigade and below computer-based applique systems; develop training technologies and simulations to improve the unaided eye and device aided night vision capabilities of Light Infantry units (FY98); and develop methodologies for training and assessing individual team member skills in virtual reality environments (FY98) (as shown in Figure IV-O-1).

Major Technical Challenges

The Army needs to develop new training and performance measurement technologies that will allow it to effectively train the full range of individual and unit tasks within budgetary constraints. Research is needed to enhance the effectiveness of new training simulation technologies such as DIS through the development of training strategies. Research has shown that the effectiveness of training aids, devices, simulators, and simulations (TADSS) is largely a function of their appropriateness to the tasks

Figure IV-O-1. Training Research in Simulated Environments. Research in the behavioral and social sciences investigates transfer of training from synthetic to actual environments. For example, an experiment demonstrated that those who rehearsed a route in a virtual environment made less navigational errors (i.e., wrong turns) when traveling through the actual building than those who only studied traditional materials (e.g., maps, photos). Of course, the best training method was practicing the route in the actual building.



that they train, and the adequacy of performance measurement and feedback techniques. Innovative training methods need to be developed which effectively use these new tools to improve overall training effectiveness. Specific challenges include:

- Develop individual and collective training strategies which provide an effective and affordable mix of live exercises and synthetic training environments to prepare soldiers to cope with the proliferation of possible missions.
- Assess the effectiveness of DIS systems to support individual, unit collective, multi-service, and joint training and use that data to maximize training value.
- Demonstrate training strategies and performance evaluation technologies to support emerging digital technologies and the accompanying new doctrine.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Manpower, Personnel, and Training is shown in Table IV-O-1.

Table IV-O-1. Technical Objectives for Manpower, Personnel, and Training

Technical Subarea	Near-Term FY97-98	Mid-Term FY99-03	Far-Term FY04-12
Manpower and Personnel	• Validate new measures of performance-related aptitude, leadership, and stress tolerance. • Structural models of the impact of peacekeeping operations on career development and commitment. • Model the development of battle commander's knowledge and skills. • Identify Force XXI NCO job requirements. • OCRs supported: BC 03, 14, 23, 26; TRD 02, 03, 04; DBS 26.	• NCO career progression recommendations. • Identify strategies and leader practices used in highly effective Special Forces team. • Techniques for developing and training battle command decision-making skills. • OCRs supported: BC 03, 14, 23, 26; TRD 02, 03, 04; DBS 26.	• Job-specific assignment tests; flexible career assignment.
Training	• Prototype training methods to facilitate the acquisition of collective skills in a DIS environment. • Minimum fidelity requirements for critical aircrew skills training. • Methodologies for training and assessing team member skills in virtual environments. • OCRs supported: BC 03, 23, 24, 25, 26; CSS 24; DBS 17, 23, 26; MTD 02, 17, 18, 20; EEL 19, 21, 22; TRD 01, 02, 04, 05.	• Combined arms and multiservices training strategies. • Aviation combined arms training strategy utilizing existing resources. • Prototype training and evaluation methods to support emerging digital equipment and doctrine. • OCRs supported: BC 03, 23, 24, 25, 26; CSS 24; DBS 17, 23, 26; MTD 02, 17,18, 20; EEL 19, 21, 22; TRD 01, 02, 04, 05.	• Advanced warfighting training strategies. • Training strategies for future aviation training devices, simulators, and simulations. • Training strategies for the future digitized battlefield.

P. Materials, Processes, and Structures

1. Scope

The Army's Materials, Processes, and Structures Program (MP&S) provides enabling technologies that are used to construct every physical system or device that the Army uses. The MP&S program provides Army-unique technology solutions and options that will increase the level of performance and durability, and reduce the maintenance burden and life cycle costs of all Army systems.

The materials subarea focuses on providing materials with the superior properties required for use in structural, optical, armor, and armament, chemical/biological/laser protection, biomedical, and Army infrastructure applications. All classes of materials are included: metals, ceramics, polymers, composites of all types, coatings, energetic, semi- and super-conductor, and electromagnetic functional materials. Meeting the performance needs of future Army systems will require synthesis of new materials, modification of existing materials, design of property specific microstructures and composite architectures, and development of advanced characterization techniques to specify microstructure, properties, and degradation modes.

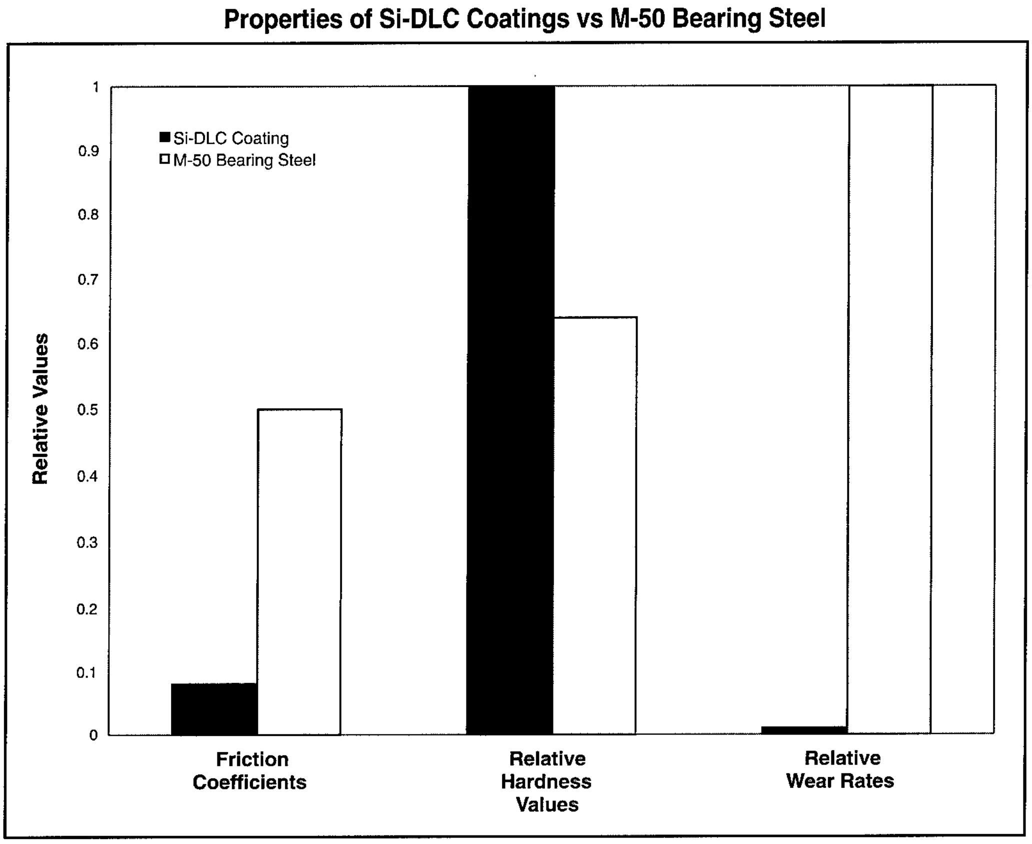
The efforts in materials processing include those technologies by which raw or precursor materials are transformed into useful materials and/or components with the requisite properties and reliability and at an acceptable cost for Army utilization. Included in the processing subarea are such technologies as casting, rolling, forging, sintering of metal or ceramic powders, polymerization, filament winding, composite processing and curing, machining, and chemical vapor deposition. Lower substrate temperature coating processes are being developed including ion beam assisted deposition (IBAD) (see Figure IV-P-1), pulsed laser deposition (PLD), and other surface modification technologies. Process modeling and control will improve quality and reduce costs of future Army materiel. Under the new paradigm of "intelligent processing," quantitative process models, artificial intelligence/expert systems, embedded sensors, and feedback/feedforward control systems are coupled so that processes can be adjusted in real time. Closely allied to "intelligent processing" are on-line nondestructive testing and inspection technology, which enhance quality and durability assurance.

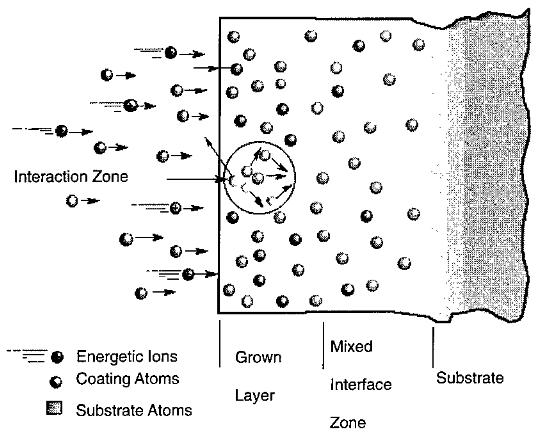
The structures subarea is aimed at demonstrating generic structures based on advanced materials and processes that meet Army specific needs such as structural elements for armored vehicle and helicopters, guns and ammunition, and missile/smart projectiles. Particular emphasis is on the development and modification of design tools and modeling for failure, fatigue, and life prediction analysis.

2. Rationale

All Army hardware critically depends upon MP&S for its performance, affordability, and durability. To the maximum extent possible, the Army relies on improvement of existing MP&S capabilities in industry, academia, and the other Services. However, the many unique Army requirements, such as thick-section ballistically efficient composite structures for combat vehicles, combat helicopter structures, chemical/biological protective materials, low-cost durable laser eye protection, transparent armor, and armaments, do not have commercial markets that support an adequate private sector R&D infrastructure. Further, there is no commercial analogue that superimposes both the severe environments and necessity of sustained high-stress use to which materials are subjected on the modern battlefield. Thus, a robust in-house MP&S technology generation program is essential to sustain the Army's current and especially its future warfighting edge. A soldier responsive in-house R&D center of excellence with a critical mass of dedicated experts is essential to focus and manage the creation, transfer, and transition of both external and internal MP&S technology advances to address Army specific requirements.

Figure IV-P-1. Environmentally Compatible Ion Beam Assisted Deposition (IBAD) Coatings for Wear Applications





PROCESS ADVANTAGES

- High coating adhesion
- High density coatings
- Control of coating stress, microstructure
- Controllable compositions

PROCESS LIMITATIONS

- Line-of-sight process
- Vacuum process

Schematic of IBAD Process

3. Technology Subareas

a. Materials

Goals and Time Frames

New materials with greatly improved properties and durability are being developed that enable major capability improvements for Army systems. For example, entirely new polymer matrix composite materials concepts that are being developed for reducing armor weight by 35 to 45 percent will also dramatically improve ballistic performance and reduce overall systems costs. This weight reduction development will have a significant impact on increasing air deployment capability. Further opportunities arise from the multifunctional capabilities of such composite material systems whereby structural, ballistic, and signature reduction improvements can be simultaneously incorporated into one material system. Ballistically efficient composites have been transitioned into the Composite Armored Vehicle-Advanced Technology Demonstration Program (CAV-ATD) during FY96.

Advanced Ceramics are under development for missile guidance domes and windows. These materials provide transparency in the required wave frequencies as well as high temperature performance and rain erosion resistance. A unique nanoscale Silicon-Nitrogen-Oxygen, Si-N-O, ceramic alloy for radome applications will be developed by FY98. Also, transparent spinel ceramics for window applications will be demonstrated by FY97. In addition, process/property optimization for recently developed high performance Barium Strontium Titanate ferroelectric materials are being refined as thick films that will enable size, weight, and cost reduction for a new generation of microwave phased array radars. This technology will transition to CECOM in FY98.

Recent advances in converting highly ordered polymers into textile fibers with outstanding strength-to-weight ratios will lead to lighter weight body armor, helmets, and shelters without reducing ballistic protection (see Section IV-F). Computer-aided design of the molecular structure of polymers will be utilized to develop improved transparent armor and controlled permeability barrier materials for protection against chemical and biological agents by FY98.[1] Higher performance heavy alloys for penetrators and warheads are essential to defeat advanced armor systems. Advanced powder metallurgical processed two-phase tungsten alloys are being developed that may provide an alternative for depleted uranium penetrators. The goal is a full-sized tungsten penetrator with equal performance to depleted uranium by FY00. Issues related to the development of advanced warhead materials are discussed in Section I, Conventional Weapons.

Improved ceramic thermal barrier coatings, wear resistant coatings, and monolithic and reinforced ceramics composites for rotorcraft and ground vehicle propulsion (see Sections IV.C and IV.S) will be demonstrated in the FY98-02 time frame. Wear resistant coatings and advanced composite materials with tailored combinations of mechanical and physical properties for reducing weight and improving durability of both conventional armaments and electric guns will be demonstrated by FY98 (see Section I).

Major Technical Challenges

While the field of materials science and engineering has made dramatic advances to materials performance by understanding the underlying role of microstructure in obtaining desired performance characteristics, many formidable scientific and technological problems still exist. Of particular importance to the Army is the ability to relate the state-of-the-art knowledge base of composition-microstructure-property parameters to models that predict behavior of materials in such complex phenomena as ballistic penetration, long term environmental exposure, and chemical agent permeation.

Specific technical challenges:

- Develop and validate models to predict the static and dynamic behavior of fiber/matrix interphases for improved synthesis and performance of polymer and/or inorganic matrix composite structural materials.
- Develop and validate predictive models for the environmental durability of monolithic and composite materials.

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1 Recent developments in polymer science, specifically dendritic polymers, are being investigated for Army applications as polymer resin and composite materials, adhesives and coatings, and electrically conducting polymers

- Develop and validate models for the interactions of gases, vapors, and liquids with polymeric barrier materials.
- Develop cost-efficient lightweight transparent armors for personnel and sensor protection.
- Design tungsten or other heavy metal alloys/ microstructures that will provide equal ballistic performance as depleted uranium.
- Develop high strength steels that combine high strength, toughness, and ballistic properties. These steels should be weldable and resistant to stress corrosion cracking.
- Model and mitigate the micromechanical failure mechanisms in elastomeric materials for Tank Track application.
- Develop improved materials for protection from agile laser threats for the individual soldier and direct view optics. Also, improved nonlinear optical materials for sensor protection devices.
- Reduce wear and erosion in armament launching components.

b. Processes

Goals and Time Frames

The MP&S program thrusts in processing science and technology focus on those processes that are required to implement the incorporation of advanced materials in Army systems. R&D on the intelligent processing of thick sections, resin transfer molded (RTM) structural composite armor materials (embedded sensors) will lead to both increased quality and reduced costs (see Figure IV-P-2). Improved process control methodologies including neural net feedback/feedforward capabilities will be demonstrated in the FY97–98 time frame, and will transition to the CAV-ATD and follow-on programs. Integration of the SMART weave process into manufacturing systems is covered in Section T, Manufacturing Science and Technology. Processing thrusts to develop low cost Ti-alloys for lightweight armor and weapons systems such as howitzers with enhanced air mobility will be demonstrated by FY98. Tape casting of multilayer Barium Strontium Titanate materials for low cost microwave phase shifters at 35 GHz will be demonstrated in FY98.

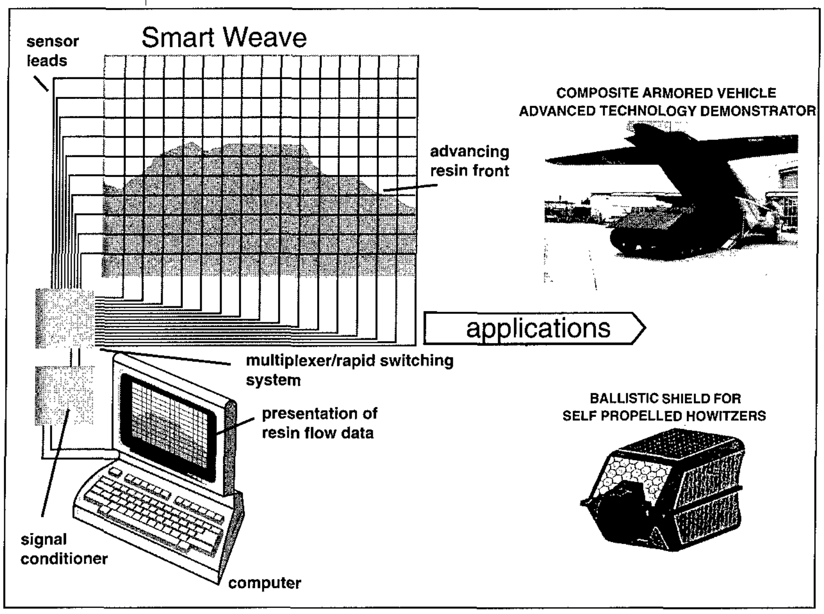
Major Technical Challenges

Much progress has been made in the area of modeling single processes and process steps. However, the integration of real-time, non-contact, or on-line sensing (especially at the very high temperatures required in liquid metal and ceramic processing) with adaptive control technology for the vast array of materials processes used by the Army is a formidable challenge.

Specific challenges:

- Develop and validate knowledge-based models for consolidation synthesis, post-consolidation thermal or thermomechanical processing, and improved capability for

Figure IV-P-2. Smart Weave, a technique for cure monitoring of resin matrix composites during processing, is an example of intelligent processing.



joining or repair of polymers, ceramics, metals, and organic and inorganic matrix composites.

- Develop process-specific sensors and control systems.
- Develop new materials processing and/or surface modification to achieve near or actual net shape components of complex geometry and variable composition and microstructural combinations to yield significantly improved tribological or structural performance in more affordable materials/design systems.

c. Structures

Goals and Time Frames

The structures portion of the MP&S technology area focuses on developing structures with a high level of structural integrity that are inspectable, analyzable, and survivable in the harsh combat environment. To be cost-effective the structural design must integrate advanced structural design concepts that are compatible with mass production manufacturing technologies. These structures can be either man rated or unmanned air or ground vehicles and hence must be designed to specific vibration and noise levels to maintain crew comfort and a low noise signature.

The results of these technological efforts have led to improved methodologies to detect and predict the onset and growth of internal damage in composite structures. This results in lighter weight and more durable structure. In the advanced concepts area unidirectional rod packs used as axial stiffening members are being evaluated (see Figure IV-P-3). Application of the rod packs reduces fiber waviness, which is detrimental to compression response. Through the integration of the rod packs in compression loaded structures, significant improvements in compression stiffness and strength have been achieved. The application of smart materials to control sound transmission through a structure has been demonstrated on fuselage like shell structures fabricated from composite materials. Reducing interior noise levels greatly improves crew comfort and reduces occupant fatigue levels.

Major Technical Challenges

- Design structurally efficient, cost-effective, and durable composite structures for Army unique ground and air vehicles as well as other structural applications.
- Develop fracture mechanics methodologies and stress analyses suited to meet Army structural needs.
- Develop NDE techniques for identification and quantification of defects and anomalies in composite structures.

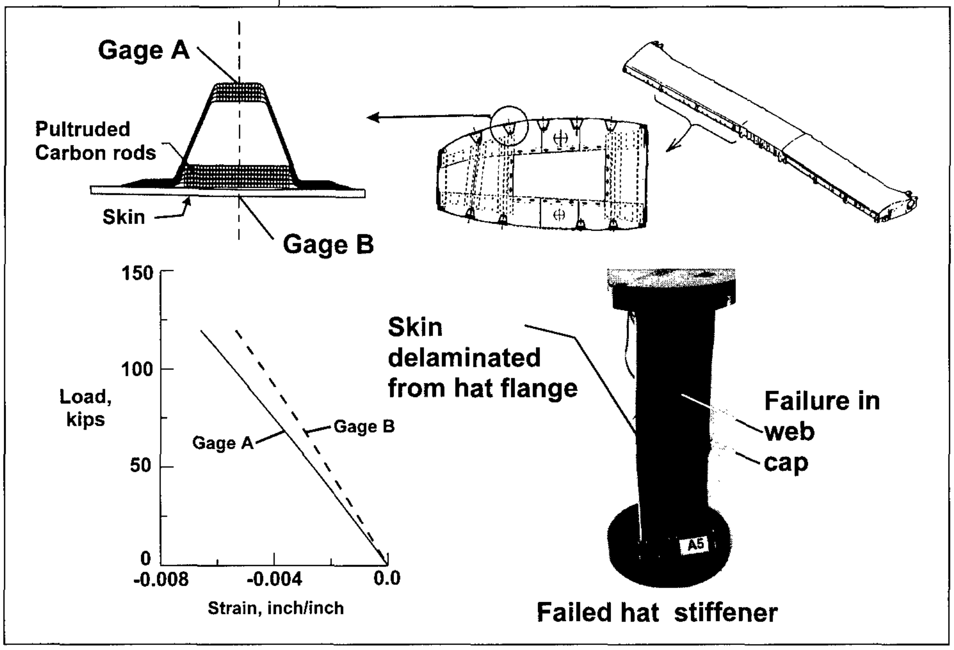


Figure IV-P-3. Unidirectional Rod Packs Used as Axial Stiffening Members

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Materials, Processes, and Structures is shown in Table IV-P-1, below.

Table IV-P-1. Technical Objectives for Materials, Processes, and Structures

Technology Subarea	Near-Term FY 97-98	Mid-Term FY 99-02	Far-Term FY 03-11
Materials	• Organic composites transitioned to CAV-ATD. • SiC & glass armor shock induced damage. • Validate Chem/Bio permeation model. • TiAl evaluated for light-weight armor. • Spinel ceramic window. • Dendritic polymers. • Broadband radar absorbing coatings. • OCRs supported: CSS 17; DBS 09, 28; EEL 08; MTD 03, 04, 08, 14.	• 25% cost reduction in organic composites. • Si-N-O nanoscale radome alloy developed. • 1st generation multi-component thin-film array for geodesic cone radar antenna. • Tungsten penetrator with DU performance. • Ceramic thermal barrier coatings for Army propulsion. • Advanced barriers for chemical defense • OCRs supported: BC 01; DBS 10; MTD 01, 02, 19.	• Composite armor with embedded sensors. • Light weight ceramics for personnel armor. • 20-30% weight reduction in personnel protection shelters. • High temperature polymers (>400°C). • Ceramic &/or metal matrix composites for tips & fins for advanced K.E. penetrators. • OCRs supported: BC 01; CSS 04; DBS 06, 08, 28; MTD 07, 11, 19.
Processes	• Smart weave control system demonstrated. • Process development for thermoplastic elastomeric propellant. • Improved welding filler metal for Alum. armor. • OMCs and C-C Composites for BMDO. • Improved clastomers for track components. • Hard, low friction Si-DLC coatings. • OCRs supported: CSS 17, 18; DSA 02; MTD 03, 04.	• Tape cast Ba-Sr-TiO multilayer phase shifter materials. • Continuous process for insensitive propellants. • Process for low cost Ti alloys (<$7/lb). • Flight test of full scale OMC & C-C forebody components. • Scale-up of Si-DLC coatings. • OCRs supported: BC 01; DSA 02; MTD 19.	• Continuous process for insensitive explosives. • Affordable rapid prototyping of inorganic composites. • Demonstrate user defined large area Si-DLC application. • OCRs supported: CSS 17; MTD 01.
Structures	• Composite rotor blades. • Energy absorbing structure. • Light weight, low cost structural concepts. • OCRs supported: CSS 17; EEL 08.	• Demonstrate user defined composite structure. • OCRs supported: MTD 03, 04, 07.	• Demonstrate composites with embedded actuators and active sound cancellation. • OCRs supported: MTD 03, 04, 07, 08.

Q. Medical and Biomedical Science and Technology

1. Scope

Military medical and biomedical science and technology programs are a unique national resource focused to yield superior capabilities for medical support and services to U.S. armed forces. Unlike other national and international medical science and technology investments, military medical research is concerned with preserving the combatant's health and optimizing mission capabilities despite extraordinary battle, non-battle and disease threats. It is also unlike most of the more widely visible Army modernization programs, because its technology is incorporated into service men and women rather than into the systems they use. This technology area is vital to the human capability dimension of all Joint Warfighting Capabilities. Weapons systems developers exploit capabilities to mitigate system hazards, improve soldier survivability and optimize operator-system interface. Because of its special and unique nature, international treaty and convention require military medical research to be conducted for the benefit of mankind. Additionally, many activities and products are regulated by the U.S. Food and Drug Administration (FDA).

The Army medical and biomedical science and technology program is divided into five technology sub-areas: Infectious Diseases of Military Importance; Medical Biological Defense; Medical Chemical Defense; Army Operational Medicine, and Combat Casualty Care. Each sub-area focuses on a specific category of threat to the health and performance of soldiers. The first four technology sub-areas emphasize the prevention of battle and non-battle injury and disease, while the Combat Casualty Care Research Program emphasizes far-forward treatment. Prevention research programs provide both medical material (e.g., vaccines, drugs, and applied medical systems) and biomedical information. Combat Casualty Care provides medical and surgical capabilities tailored to military medical needs for resuscitation, stabilization, evacuation, and treatment of all battle and non-battle casualties. Each technology sub-area has objectives that respond to the National Military Strategy.

The National Defense Act of FY94 consolidated Chemical and Biological Defense (CBD) Programs, including both Warfare and Medical, under OSD management. The medical CBD programs are discussed here, while the warfare CBD programs are addressed in Section E, *Nuclear, Chemical, and Biological Defense*, of this chapter.

2. Rationale

Individual service men and women are the most important, and the most vulnerable, components of military systems and mission capabilities. Disease and non-battle injury typically far outweigh battle-related injury as the greatest cause of casualties among military forces. Regional, life-threatening, or incapacitating disease epidemics both limit and constrain military deployment alternatives. Widespread sickness and injury are mission aborting; high casualty and death rates are warstoppers. The current force structure is confronted with an expanded potential for large-scale regional conflicts, proliferation of weapons of mass destruction, and ready availability of advanced conventional weapons, as well as more diverse and highly complex missions characterized by continuous, high-tempo operations. These more dangerous challenges are coupled with enduring threats of disease, harsh climates, operational stress, and injury. These realities mandate a sustained commitment to robust investment in medical research programs (Figure IV-Q-1).

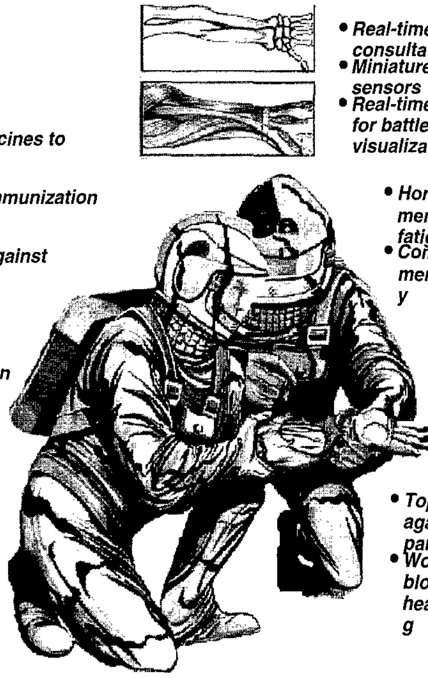
3. Technology Sub-Areas

a. Infectious Diseases of Military Importance

Goals and Time Frames

The goals of the Military Infectious Disease Research Program are to protect soldiers from incapacitating infectious diseases by the development of vaccines and disease preventing drugs and to return soldiers to duty by the discovery of effective drug treatment. Infectious diseases

Figure IV-Q-1. Future Medical Technologies



pose a significant threat to operational effectiveness. Most Americans lack natural immunity to diseases endemic abroad. Prevention of epidemic infections in deployed forces is a force multiplier. Immunization prior to deployment is the preferred medical countermeasure to infection because it reduces logistical requirements in the theater of operations. Chemoprophylaxis is a proven method of protecting the military population from malaria. Sepsis following surgical wound infection is a major cause of death in battle casualties. Lost training days due to respiratory infections and meningitis increase the cost of mobilization. Human Immunodeficiency Virus (HIV) infection is a leading cause of death among young people of military age.

A vaccine to protect troops against infectious hepatitis was fielded (FY95). New antimalarial drugs will be fielded to replace drugs rendered ineffective by the global development of parasite resistance (FY97). An improved drug for the treatment of cutaneous and visceral leishmaniasis will replace the highly toxic and marginally effective compound currently available (FY97). Improved arthropod repellents will protect soldiers from insects carrying lethal parasitic, viral, and rickettsial diseases (FY97). Oral vaccines will immunize soldiers against incapacitating dysentery caused by shigella species (FY98). Antibodies will provide protection against sepsis resulting from the common bacterial wound infections (FY98).

Major Technical Challenges

Many diseases which were feared killers only a few years ago have been subdued, largely through vaccination and public health advances. The first diseases to yield were those in which vaccination induces permanent immunity. New diseases (such as HIV, Lyme disease, Legionnaire's disease) emerged to take their place while previously successfully treated diseases developed resistance to formerly effective drugs. The focus of market-driven pharmaceutical development has been on diseases important in the industrial world. Infections prominent in many strategically significant areas of the world do not receive attention comparable to the extent of the populations affected. Thus, fundamental insight into the biology of the infectious organism and human response to infection must be developed through Army supported research. Drug and vaccine development requires the use of animal models of human infections to validate their efficacy. In many cases, such as malaria, the species of parasite which will infect laboratory animals is not the same species as that affecting humans. Furthermore, the course of infection in animals may not produce the symptoms important in human disease.

Specific technical challenges are listed below:

- Develop rodent blood and tissue systems which allow growth of human malaria parasites in laboratory animals.
- Develop animal models for dysentery.

- Detect and identify neutralizing antibodies produced in minuscule amounts.
- Formulate vaccines to maximize the immune response.
- Design drugs which will evade parasite defenses.
- Grow hepatitis E virus and vivax malaria parasites in cell culture.
- Improve the diagnosis of leishmaniasis.
- Develop rapid methods to differentiate drug-resistant from drug-susceptible malaria and typhus infections.
- Improve capacity of recombinant vaccines to stimulate a protective immune response.
- Determine the molecular components of infectious organisms that initiate a protective immune response in humans.
- Discover a replacement insect repellent for DEET.
- Validate safety of multicomponent vaccines.
- Develop vaccines effective against geographic variants of disease.

b. Medical Biological Defense

Effective FY94, as a result of Public Law 103-160, the National Defense Authorization Act for Fiscal Year 1994, the medical chemical and biological defense research programs were consolidated under a single office of OSD with the Army serving as Executive Agent.

Goals and Time Frames

The primary goal of the Medical Biological Defense Research Program (MBDRP) is to ensure the sustained effectiveness of U.S. armed forces operating in a biological warfare (BW) environment. Specific objectives of the program are: To prevent casualties by the use of medical countermeasures (e.g., vaccines, toxoids, and pre-treatment drugs); to diagnose exposure to a BW agent; and to use chemotherapeutics and immunotherapeutics to prevent lethality, and maximize return to duty.

The MBDRP is developing vaccines that will protect at least 80 percent of the immunized personnel against an aerosol challenge and will induce minimum reactogenicity in soldiers when immunized. Safety and efficacy in pre-clinical studies using animal models will be demonstrated for the following vaccines: second generation Anthrax vaccine (FY96); Venezuelan equine encephalitis vaccine (FY96); second generation Botulinum Toxin vaccine (FY98); Plague vaccine (FY98); Eastern equine encephalitis vaccine (FY98); Brucellosis vaccine (FY99); second generation Ricin vaccine (FY00); and the second generation Staphylococcal Enterotoxin B vaccine (FY00). After these successful transition milestones, initial clinical trials will be conducted.

Major Technical Challenges

The development of new vaccines requires both close examination of the biological threat agent to determine the pathogenic mechanism of the disease and development of vaccine strategies to counteract these mechanisms. Strategies for vaccine development must embrace new knowledge regarding the human immune system. This includes information about generation of immunity; the preservation of immunological memory; and the regulation or modulation of immune functions, including enhancement and suppression.

New candidate vaccines must be both safe and efficacious. These criteria are regulated by the Food and Drug Administration (FDA). Ethically it is not possible to test the efficacy of a biological warfare vaccine in humans, however extensive safety and immunogenicity studies are conducted in these development programs.

Therefore, this testing must be conducted in model systems. Animal models do not currently exist for many of the BW agents. The use of existing animal models is limited by the desire to decrease or eliminate the use of animals for vaccine development.

Specific technical challenges are listed below:

- Develop appropriate animal models to test the safety and efficacy of medical countermeasures.
- Increase genetic and biologic information applicable to medical countermeasures against threat agents.
- Exploit the human immune system to provide protection against threat agents.
- Analyze new vaccine delivery systems and multi-agent vaccines.

c. Medical Chemical Defense

Effective FY94, as a result of Public Law 103-160, the National Defense Authorization Act for Fiscal Year 1994, the medical chemical and biological defense research programs were consolidated under a single office of OSD with the Army serving as Executive Agent.

Goals and Time Frames

The mission of the Medical Chemical Defense Research Program is to preserve combat effectiveness by timely provision of medical countermeasures in response to joint service chemical warfare defense requirements. This goal is accomplished via three objectives: To maintain technological capability to meet present requirements and counter future threats; provide individual level prevention and protection to preserve the fighting strength; and provide medical management of chemical casualties, to enhance survival and expedite and maximize timely return to duty.

By FY96, demonstrate the safety and efficacy for a Milestone 1 transition (demonstration and validation phase) to advanced development for a methemoglobin former for pretreatment of cyanide. Demonstrate by FY96 safety and efficacy sufficient for a Milestone 0 transition (concept exploration and definition) of an advanced anticonvulsant component for the warfighter/buddy-use nerve agent antidote. By FY99, develop biotechnology-based chemical agent prophylaxes that provide protection against battlefield concentrations of CW agents without operationally significant physiological or psychological side effects. Demonstrate by FY99 safety and efficacy sufficient for a Milestone 0 transition of a reactive component for a topical skin protectant (providing protection against penetration) that will detoxify both vesicant and nerve agent. By FY00, demonstrate safety and efficacy of a candidate medical countermeasure against the vesicant agents sufficient for a Milestone 0 transition decision. By FY02, demonstrate safety and efficacy sufficient for a Milestone 0 transition decision of an advanced skin/wound decontamination system for decontaminating chemically contaminated wounds.

Major Technical Challenges

Developing a pretreatment, protectant, or antidote which is both effective against chemical warfare agents and safe for human use is critical. Candidate countermeasures must demonstrate the desired protection without detrimental side effects. These evaluations depend on animal models to identify those candidates with the highest potential to successfully demonstrate both safety and efficacy in warfighters.

Specific technical challenges are listed below:

- Identify appropriate experimental model systems to predict drug or treatment efficacy and safety in humans.
- Develop pretreatment/antidotes with special characteristics (e.g., quick-acting, long-acting, easy to carry/use).
- Generate immune response to small molecules.
- Develop expression vectors for recombinant products.
- Synthesize reactive/catalytic decontaminant and demonstrate safety of the decontaminant and protectant compounds.

d. Army Operational Medicine

Goals and Time Frames

The goals of the Army Operational Medicine Research Program are to protect soldiers from environmental injury and materiel/system hazards; shape medically-sound safety and design criteria for military systems; sustain individual and unit health and performance under operational stresses, especially continuous and sustained operations (CONOPS/SUSOPS); and quantify performance criteria and soldier effectiveness in order to improve operational concepts and doctrine.

The modern warfighter will require the full range of human physical and mental capability to survive and prevail in future military operations. By FY96, predictive models will be developed to estimate the level of performance degradation from nonincapacitating laser eye injury. By FY97, performance enhancing rations involving an optimal carbohydrate mix and other components such as caffeine, tyrosine and choline will prevent neurochemical deficits and sustain soldier cognitive function during CONOPS in environmental extremes. Antioxidant pretreatments will be tested for the ability to protect soldiers against muscle damage produced by blast overpressure or sustained physical effort (FY98). Flat panel displays will be designed to reduce the effects of visual cortical distortions and disorientation in rotary-wing aviators and command ground vehicle crewmembers (FY98). By FY98, melatonin, a hormone which acts as a master synchronizer of body rhythms and a natural sleep inducer, will be operationally tested for ability to prevent symptoms of jet-lag and fatigue in soldiers deploying across time-zones and in night operations. Specific physical and psychological training strategies will be developed to harden selected individuals to operate continuously without performance deficit or injury for 72 hours (FY98).

Major Technical Challenges

Developing strategies and products to protect, sustain and enhance soldier performance requires the development and application of scientific data and knowledge. Strategies and products must remain effective in various combinations and in realistic operational tests. One example is sleep management. Strategies that combine the use of pharmaceutical agents, naturally occurring hormones (such as melatonin), timing of bright lights, and feeding schedules are needed. Various combinations of these factors must be explored in order to develop the best sleep management strategies for the most realistic operational scenarios.

Specific technical challenges are listed below:

- Identify flat panel design criteria or psychological training interventions which will prevent instrument myopia and spatial disorientation problems.
- Develop physical and psychological training strategies using biomechanical, psychological, and physiological evaluations in a wide variety of CONOPS/SUSOPS scenarios.
- Identify the interactions between tyrosine and caffeine in maintenance or enhancement of adrenergic activation following prolonged stress and overcome problems of variable effects in different individuals.
- Develop an optimal treatment regimen for melatonin to resynchronize sleep cycles and demonstrate that there are no significant side effects in male or female soldiers in field studies with realistic stressors.

e. Combat Casualty Care

Goals and Time Frames

The goal of this program is to save lives far-forward. This goal will be achieved by improving the delivery of far-forward resuscitative care, minimizing lost duty time from minor battle and non-battle injuries, reducing unnecessary evacuations, and decreasing the resupply requirements of all forward echelons of care. Near-term objectives include general improvements in currently approved treatments, techniques, solutions, etc. Specifically, by FY96, develop small-volume resuscitation solutions such as hypertonic saline dextran (HSD). Such solutions will reduce the logistics tail by at least threefold for the 5 to 10% of casualties requiring HSD. By FY96 produce an intraosseous, blood vessel infusion device for the rapid administration of resuscitation solutions, which will enable prompt vascular access in those casualties in profound shock. The program will also provide a microencapsulated antibiotic to improve drug concentrations at the required tissue site, without overwhelming the entire body by FY96. Mid-term goals include introduction of capabilities to physiologically monitor combat casualties from the instant they are wounded (FY99), development of improved diagnostic algorithms, introduction of minimally invasive "smart catheters" for the determination of blood chemistries on the far-forward battlefield (FY01), development and fielding of oxygen free radical scavengers to minimize the damage to cells and tissue caused by the rigors of combat trauma, as well as products to reduce blood loss following injury. Longer lived blood preservatives are scheduled for transition during this period (FY97-01), as are improved medications for the treatment of thermally injured tissue.

Major Technical Challenges

Technical challenges include understanding and overcoming the toxicity of oxygen-carrying hemoglobin solutions, development of battery power and computing capability necessary to support the demands of the computer-aided diagnostic sensor/computer interface system, overcoming the problem of applying local hemostatic agents (e.g., fibrin glues) to the wet surfaces of a hemorrhaging wound, and miniaturizing all of the equipment necessary to induce suspended animation far-forward.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Medical and Biomedical S&T are shown in Table IV-Q-1, below.

Table IV-Q-1. Technical Objectives for Medical and Biomedical Science and Technology

Technology Subarea	Near-Term FY97-98	Mid-Term FY99-03	Far-Term FY04-12
Infectious Diseases of Military Importance	• Vaccine Vectors. • Synthesized antiparasitic drugs. • Genetically engineered vaccines. • OCRs supported: CSS 01; CDD 11; DBS 06, 07; EEL 21, 25.	• Peptide synthesis. • Countermeasures to parasitic drug resistance. • Proteosome delivery. • Single step field assays. • Advanced adjuvants. • OCRs supported: CSS 01; CDD 11; DBS 06, 07; EEL 21, 25.	• Combined oral vaccines. • Topical antiparasitic drugs. • Gene therapy. • Single dose vaccines. • OCRs supported: CSS 01; CDD 11; DBS 06, 07; EEL 21, 25.
Medical Biological Defense	• Microencapsulated vaccines. • Genetically engineered vaccines. • Monoclonal antibodies. • Confirmation diagnostics. • OCRs supported: CSS 01, 12, 21.	• Bioengineered toxin scavengers. • Human monoclonal antibody therapy. • Synthetic peptides. • Proteosome delivery. • OCRs supported: CSS 01, 12, 21.	• Nucleic acid immunization. • Combined oral vaccine. • Receptor-targeted therapeutic agents. • OCRs supported: CSS 01, 12, 21.
Medical Chemical Defense	• Cyanide pretreatment. • Topical skin protectant. • Nerve agent exposure field diagnostic test kit. • Cyanide exposure field diagnostic test kit. • OCRs supported: CSS 01, 12, 21.	• Catalytic pretreatment for nerve agents. • Advanced anticonvulsant. • Reactive topical skin protectant. • Multishambered autoinjector. • OCRs supported: CSS 01, 12, 21.	• Catalytic scavengers for broad range of CW agents. • Medical countermeasure against vesicants. • Immunoprophylaxis for CW agents. • OCRs supported: CSS 01, 12, 21.
Army Operational Medicine	• Blast standards to protect soldiers from injury. • Laser effects model. • Pharmacological strategies to enhance restorative sleep. • Training strategies to enhance upper body strength and endurance. • Heat stress model to predict soldier performance decrements. • OCRs supported: CSS 10, 12, 13, 20, 21; BC 01, 02, 05, 13; DSA 16; DBS 06, 06; EEL 09' MTD 18, 21.	• Strategies to prevent blast-induced performance decrements. • Laser injury treatments. • Non-phamacological strategies to enhance crew-rest. • Training strategies to optimize specific physiological capabilities. • Strategies to reduce heat stress (e.g., glycerol drink, vasodilation). • Performance-enhancing ration components. • OCRs supported: CSS 10, 12, 13, 20, 21; BC 01, 02, 05, 13; DSA 16; DBS 06, 06; EEL 09; MTD 18, 21.	• Physiological status monitor. • Sleep/alertness enhancers. • Treatments for laser retinal injury. • Memory enhancers. • Non-steroidal strength enhancers. • OCRs supported: CSS 10, 12, 13, 20, 21; BC 01, 02, 05, 13; DSA 16; DBS 06, 06; EEL 09; MTD 18, 21.
Combat Casualty Care	• Intraosseous infusion device. • Microencapsulated antibiotic. • OCRs supported: BC 01, 02, 05, 13; CSS 10, 12, 13, 20, 21; DSA 16; DBS 06, 07; EEL 09; MTD 18, 21.	• Improved blood preservative. • Small volume resuscitation fluid. • Rapid fluid warmer and infusion device. • Lazeroid therapy for massive tissue trauma. • OCRs supported: BC 01, 02, 05, 13; CSS 10, 12, 13, 20, 21; DSA 16; DBS 06, 07; EEL 09; MTD 18, 21.	• Hibernation drug. • Blood substitutes. • Oxygen free-radical scavengers. • Life support capsule for casualty. • Non-invasive physiological sensors. • Diagnostic decision assist algorithm. • OCRs supported: BC 01, 02, 05, 13; CSS 10, 12, 13, 20, 21; DSA 16; DBS 06, 07; EEL 09; MTD 18, 21.

R. Sensors

1. Scope

By providing critically required military capabilities detailing troop positions, target locations, and battlefield conditions, sensors, and information processing technologies form an enabling array of systems on Army Platforms. Flexible robust sensor systems have significantly increased Army warfighting capabilities and become a true force multiplier. Sensor technologies depend upon research provided by ARO, the RDECs, ARL, and Federated Partners. This area develops technologies in five subareas: Radar Sensors; Electro-optic Sensors; Acoustic, Magnetic, and Seismic Sensors; Automatic Target Recognition; and Integrated Platform Electronics.

2. Rationale

Sensor technology provides the "eyes and ears" for nearly all Army tactical and strategic weapon systems as well as the intelligence community. Sensors support effective battlefield decision making and contribute to achieving the JCS Top Five Future Joint Warfighting Capabilities. Sensors represent a major cost factor for weapon systems which is addressed in this program through a number of thrusts, including affordable integrated circuits, ultra-large and multicolor infrared focal plane arrays, multifunction multiwavelength lasers, common modules, shared apertures, computer simulation and modeling, and adaptive processing. Expected payoffs include 50 percent reduction in cost of imaging radars and infrared search track sensors, and 10 to 1 improvement in thermal sensitivity of infrared sensors. Sensors are integral and fundamental to achieve situational awareness on the battlefield to win the information war. Because of their pervasiveness, sensors have multiple transition opportunities, including the 21st century soldier, and sensors are vital to the survivability of soldiers and the weapon platforms on the battlefield.

3. Technology Subareas

a. Radar Sensors

Goals and Time Frames

Radar is the sensor for all weather detection of air, ground, and subsurface targets. This subarea involves technology developments involving enhanced and new capabilities associated with wide area surveillance radars, tactical reconnaissance radars, and airborne and ground fire control radars. Objectives include the understanding of the phenomenology and applications of ultra wideband (UWB) synthetic aperture radar (SAR) to enable detection and classification of stationary targets that are subsurface or concealed by foliage or camouflage. This technology would enable development of a foliage penetration (FOPEN) radar capable of real-time image formation in operational scenarios. The system could be expanded to support a ground penetration (GPEN) radar capable of collecting subsurface target data.

Another primary goal is the research and development of affordable battlefield fire control radar (FCR) technology to improve detection, tracking, and discrimination of high value stationary and moving targets for the Longbow Apache and Comanche programs as well as vehicle-based systems such as the MGR in TA-ATD and the Rapid Target Acquisition system for crew-served TOW.

Augmenting the programs listed above are fundamental studies of the phenomenology associated with target acquisition such as target and clutter characteristics, resolution enhancement techniques, and algorithm studies, such as the Real Aperture Stationary Target Radar (RASTR) program, which are designed to investigate performance enhancements through evaluation of improvements in a software environment based on high resolution data sets. Milestones are as follows: begin test of GPEN Crane SAR (FY97); collect data and analyze ATR algorithm performance (FY99); complete Ka-Band Polarimetric Monopulse radar to support MGR studies (FY98); apply Direct Digital Synthesizer (DDS) and wideband transceiver technology development to stationary target fire control radars (FY97-99); improve stationary target algorithms to allow for autonomous adaptation to various clutter backgrounds and strive for a probability of detection greater than 80 percent with false alarm rates much less than 0.1/km2.

Major Technical Challenges

Major technical challenges include development of instrumentation for the understanding of wave propagation in background/clutter environments; development of high power, low frequency, wideband signals; and development of radar components and algorithms that support high probability of detection and classification of stationary and moving targets with low false alarm rates.

Specific technical challenges are highlighted below:

- Real beam search on-the-move targeting for stationary ground targets.
- Buried target detection.
- Enhanced spatial resolution for operational radar.
- MMW E-scan antennas.
- Affordability by design.

b. Electro-Optic Sensors

Goals and Time Frames

The goal of tactical EO sensors is to provide passive/covert and active target acquisition (detection, classification, recognition, identification) of military targets of interest and also to allow military operations under all battlefield conditions. Platforms using EO sensors include dismounted combat personnel, ground combat and support vehicles, tactical rotary-wing aircraft, manned/unmanned reconnaissance aircraft, and ballistic/theater missile defense. Major milestones are as follows: NIR LADAR for RSTA (FY97), thin film low cost uncooled sensors and smart dual color sensors (FY99), multidomain smart sensors with shared aperture (FY03), and integrated detector arrays which incorporate advanced diffractive optics and/or post processing circuitry (FY03).

Major Technical Challenges

Technical roadblocks to overcome include:

- The growth of thin film materials for uncooled detectors.
- Onchip readout circuits for AD conversion and neuromorphic circuits.
- Monolithic integration of detector, read out, and processing modules.
- Low light level solid-state sensors.
- Fusion algorithms for multidomain sensor system.
- Sensor performance in naturally occurring and battlefield generated countermeasures.
- Multidomain signature data bases.
- Design of Diffractive Optical Elements (DOEs).
- Integration of DOEs, detectors, and post processing circuitry in single device.
- Effective, affordable laser hardening for multifunction, multiband laser sources for active sensors.
- Multifunction, multiwavelength laser sensors.

c. Acoustic, Magnetic, and Seismic Sensors

Goals and Time Frames

The objective of this program is to provide real-time tracking and target identification for a variety of battlefield ground and air targets. Objective systems include unattended surveillance sensors and target engagement sensors. Advances in signal processing devices and techniques have made acoustic sensors realizable and highly affordable. Both continuous signals, such as engine noise, and impulsive signals, such as gun shots, are of interest. Enhancing hearing for individual soldiers is also important, and efforts are underway to extend the audible range and frequency response of an individual soldier. Goals include enhanced tracking and identification algorithms, creation of a robust target signature database and algorithm development laboratory (FY97), and detection and tracking of large formations of battlefield targets (FY98).

Major Technical Challenges

Areas of technical risk are driven largely by the immature nature of battlefield acoustics technology. Advances in digital signal processing will allow new algorithms to be implemented in affordable packages. Specific technical challenges include:

- Advanced target identification algorithms.
- Multitarget resolution.

- Detection and identification of impulsive acoustic signatures.
- Platform and wind noise reduction techniques.
- Compact array design for long range hearing.

d. Automatic Target Recognition (ATR)

Goals and Time Frames

ATR systems will provide sensors with the capability to recognize and identify targets under real-world battlefield conditions. ATR technologies and systems will increase the capabilities of sensors far beyond today's capabilities. They will provide the future U.S. Army with target recognition and identification capabilities that will maintain and increase dominance over all adversaries.

Just as sensor systems are the "eyes" for tactical and strategic weapon systems, ATR systems will provide the "brains" for these weapon systems. ATR systems and technologies will allow weapons systems to automatically identify targets, (1) increasing lethality and survivability, (2) reducing the cost of employing advanced high priced weapons, and (3) eliminating or at least reducing the cost and tragedy of losses from friendly fire. In addition, ATR will aid the image analyst to screen the ever-expanding imagery derived from high resolution, wide field-of-view SAR systems.

In the near term (FY97-98) the Army's goals in ATR are to do 10 target classes, with identification rates nearing 75 to 80 percent and significantly reduced false alarm rates. In the mid term (FY99-03), ATR systems will handle 20 target classes with improved detection and false alarm rates. In the far term (FY04-12), 100 target classes will be handled with additional improvements in performance.

Major Technical Challenges

Technology areas that are integral to ATR include processors, algorithms, and ATR development tools, which include modeling and simulation. Today, the focus is on both single sensor and multiple sensor ATR algorithm development. While processor development is being successfully leveraged off the highly competitive commercial market and the importance of development tools remains high, single and multiple sensor algorithm development programs are the key to successful development of ATR systems for the U.S. Army. Ongoing data-driven and model-based algorithm development programs are providing exciting results that include detection rates approaching 100 percent, identification rates in the 80 percent range, and significant reductions in false alarms. In the mid and far term these developments translate into fielded ATR systems that will significantly increase soldiers' capabilities and reduce their workload.

e. Integrated Platform Electronics

Goals and Time Frames

Integrated Platform Electronics (IPE) focuses on the integration technologies, disciplines, standards, tools, and components to physically and functionally integrate and fully exploit electronic systems on-board airborne (helicopters, RPV, and fixed wing), ground, and human platforms. Integrated electronics approaches typically result in systems at half the cost and weight of conventional approaches, while providing virtually 100 percent of platform mission capability. One milestone will be to demonstrate an optical backplane system that will provide 40 percent increase in bandwidth (FY98).

Major Technical Challenges

Determine an architecture or set of architectures which prove sufficiently robust to readily accept technology innovations developed in the commercial sector. Improve reliability to reduce logistics, deployability, and support costs. Develop standardized image compression techniques and architectures to permit transfer of images with sufficient clarity and update rates to support digitization of the battlefield.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Sensors is shown in Table IV-R-1, below.

Table IV-R-1. Technical Objectives for Sensors

Technology Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Radar Sensor	• Complete Ka-Band database of targets and clutter. • Develop Ka-Band Polarimetric Monopulse radar Test Bed. • Demonstrate Rapid Target Acquisition Concepts. • Field Test Crane SAR. • OCRs supported: BC 01, 20, 22; DSA 02, 09, 14; DBS 01A, 03, 09, 14, 16; MTD 02, 10, 19; EEL 10.	• Demo radar for TUAV. • COTS processor for Target Acquisition. • STI algorithm insertion in MGR for TA-ATD. • Demo UWB FOPEN SAR-All Wx, wide area detection of targets in foliage. • Reduce antenna size requirement by 50%. • OCRs supported: BC 01, 20; DSA 02, 09, 14; DBS 01A, 03, 09, 14, 16; MTD 02, 03, 10, 19; EEL 10.	• Demonstrate fully integrated wide-band digital receiver for battlefield radar. • Demo UWB GPEN capabilities against distributed targets. • Implement coherent G-Band radar for fire control. • OCRs supported: BC 01, 20; DSA 02, 09, 14; DBS 01A, 03, 09, 14, 16; MTD 02, 10, 19; EEL 10.
Electro-Optics Sensors	• High resolution Image Intensifier System. • Dual color sensor demonstration. • Quantum Well array sensor. • Advanced material for uncooled sensor. • OCRs supported: BC 01; CSS 01; MTD 01, 19; DBS 01A, 02B, 08; DSA 12.	• NIR ladar sensor for RSTA. • AIMS-Lightweight sensor and display modules for multiple infantry missions. • Thin film low cost uncooled sensor. • Dual color smart sensor. • OCRs supported: BC 01, CSS 05; MTD 01, 02, 11, 19; DBS 01A, 02B, 06, 08; DSA 12; EEL 06, 13.	• Multi domain smart sensor system with shared aperture. • OCRs supported: BC 01; CSS 05; MTD 02, 11, 19; DBS 01A, 02B, 08; DSA 12; EEL 06, 13.
Acoustic, Magnetic and Seismic Sensors	• Develop improved target identification algorithms. • Develop advanced beam forming algorithms. • Demonstrate advanced acoustic target acquisition, tracking & ID in real time. • OCRs supported: BC 01; DSA 03, 04; DBS 03, 04; MTD 02, 05, 01; EEL 01, 12.	• Develop advanced laboratory capability to evaluate acoustic algorithms. • Establish robust signature database. • Develop tracking & ID algorithms for large target formations. • Develop long range hearing capability for dismounted soldier. • OCRs supported: BC 01; CSS 02; DSA 03, 04, 14; DBS 01, 03, 04; MTD 01, 02, 05, 19; EEL 01, 12.	• Develop infrasonic detection and tracking techniques. • Develop advanced noise reduction techniques. • Develop target identification capabilities to classify signature fine structure. • OCRs supported: BC 01; CSS 02; DSA 03, 04, 14; DBS 01, 03, 04; MTD 01, 02, 05, 19; EEL 01, 05, 12.
Automatic Target Recognition Sensors	• Multi-sensor ATR's providing 80% open target recognition. • 6X search rate. • 10 target classes. • OCRs supported: BC 01; DSA 09; MTD 02, 12; DBS 01A, 04A.	• Multi-sensor ATR's providing 90% recognition of ground targets in mod-high clutter with acceptable false alarms. • 60X search rate. • 20 target classes. • OCRs supported: BC 01; DSA 02, 09,13; DBS 01A, 04A, 13; MTD 02, 12, 19.	• Multi-sensor ATR's providing 95-97% recognition with acceptble false alarms. • 1000X search rate. • 100 target classes • OCRs supported: BC 01; DSA 06, 09, 13; DBS 01A, 04A, 13; MTD 02, 12, 19.
Integrated Platform Electronics	• Reduce Tank crew manning 50%. • Demonstrate super high density connector on SEM-E module. • OCRs supported: BC 11, 22; DSA 08, 15; EEL 11, 12; MTD	• Improve Navigation technology by one order of magnitude in all environments. • Demonstrate tank crew 50% reduction using crewman's associate integration. • OCRs supported: BC 22; DBS 16; EEL 11, 12; MTD 02, 03, 19.	• Demonstrate immersion cooled SEM-E>1000 watts • Demonstrate 20 GHz network for combined digital, video, RF. • OCRs supported: BC 01, 09, 11, 22; DSA 08, 15; MTD 02, 03, 19.

S.

Ground Vehicles

1. Scope

The Army focuses its ground vehicle technologies on those that provide our soldiers the capabilities needed to "Dominate the Maneuver" and "Win the Information War." The Ground Vehicle Technology Area incorporates efforts to support the basic Army and Marine Corps land combat functions: shoot, move, communicate, survive, and sustain. This technology area comprises the following subareas: Systems Integration, Vehicle Chassis and Turret, Integrated Survivability, Mobility, and Intra-Vehicular Electronics Suite. These subareas are illustrated in Figure IV-S-1.

2. Rationale

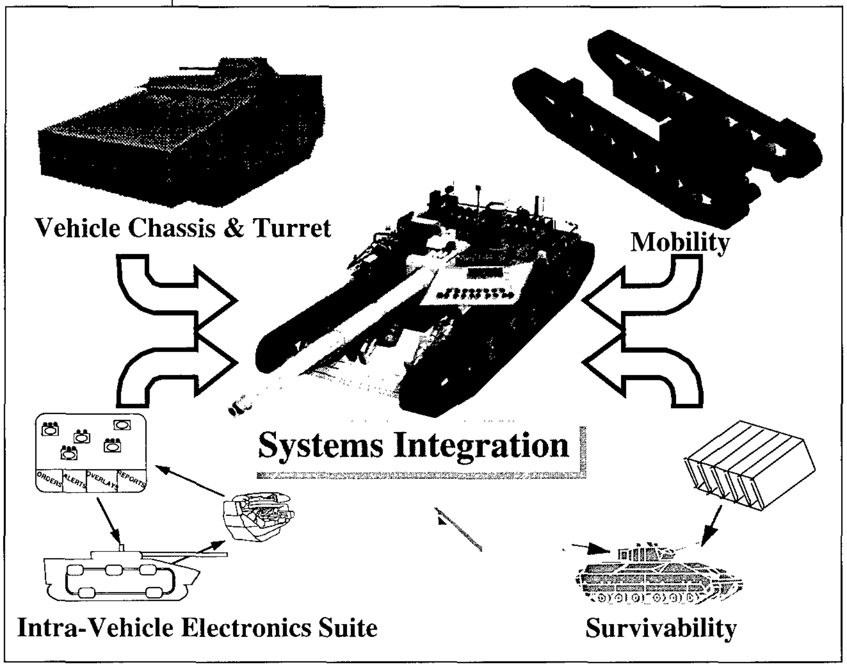
One of the Mounted Forces' most critical deficiencies in the post-Cold War era is the inability to rapidly deploy forces for worldwide contingency missions. Current Mounted Forces are capable but take too long to be deployed, have a large logistics tail, and are ill-suited to the third world infrastructure. Current combat vehicles rely on traditional materials for construction, communications, training, passive armor protection against munitions, and conventional mobility.

A lighter "heavy" force is required that can deploy to sea in less time, with fewer ships, and reduced Combat Services Support (CSS) requirements and yet be equally lethal, survivable, and cost-effective. Materiel, Smart Weapon, and Survivability advances can lead to a fully air deployable armored assault force or a more deployable heavy assault force requiring 50 percent or less of current logistics assets.

Ground vehicle platforms require targeting, location, and acquisition systems capable of rapid detection, recognition, identification, hand-off, or engagement of both ground and aerial targets beyond the threat's detection range. Systems must perform effectively day or night in adverse weather, in cluttered background environments, and in the presence of countermeasures to include jamming, screening, and the use of low observable and active defense systems. Ground vehicle platforms must possess the capability to execute improved maneuver tempo as a result of digitizing the battlefield.

Through the Integrated Concept Team (ICT) process, the user now has greater influence over Science and Technology (S&T) planning. The ICTs at the U.S. Army Armor Center, Fort Knox, have refocused near-term S&T towards the Future Scout and Combat System (FSCS) and Abrams Tank modernization. Far-term S&T will be focused towards the next generation "tank." Detailed ICT ground vehicle activities are described in Section III-G, Mounted Forces.

Figure IV-S-1. Advanced Ground Vehicle Technologies for the Mounted Force



3. Technology Subareas

a. Systems Integration

Goals and Time Frames

Systems Integration/Virtual Prototyping of future vehicles utilizes modeling and simulation and system level advanced technology demonstrators to: (1) to develop preliminary concepts; (2) optimize design; (3) maximize force effectiveness for ground vehicles; and (4) drive technology goals. STO IV.S.5 supports ground vehicle virtual prototyping. Future vehicle concepts and designs are the realization of the Army and Marine Corps user's requirements and the opportunities harvested from the results of previous technology subsystem development programs.

The goal is to demonstrate the feasibility and potential of lighter, more lethal, and survivable ground combat vehicles. Four types of modeling and simulation will be employed: engineering models, constructive simulation, distributed simulation, and virtual reality prototyping. The analyses conducted will span the entire vehicle combat spectrum and will be performed physically, analytically, and interactively using simulation methodologies. Virtual concepts and designs will mirror technology and can be readily evaluated for mobility, agility, survivability, lethality, and transportability, forming the basis for validation, verification, and accreditation. By 1997, virtual vehicle concepts representing superior revolutionary battlefield technologies will be developed, and combat effectiveness will be demonstrated via constructive and virtual simulation. By 2000, complete validation of Virtual Prototyping process.

Major Technical Challenges

The major challenge is to provide the user with systems that can attain an effective balance between increased fighting capability, enhanced survivability, and improved deployability, while also meeting or exceeding operational effectiveness, cost, manufacturing, and reliability/maintainability goals.

b. Vehicle Chassis and Turret

Goals and Time Frames

Through the use of composite, titanium-based, and other lightweight materials, technologies are being developed that will make future combat vehicles more lightweight and deployable (33 percent lighter structural/armor combination), versatile (multiple combat and support roles), and survivable (better ballistic protection and reduced signature). These technologies will be developed for combat vehicles to optimize and exploit the structural integrity, durability, ballistic resistance, repairability, and signature characteristics of a vehicle chassis and turret fabricated primarily from composite and/or titanium-based materials. Current vehicle chassis activities revolve around the development of vehicles composed of advanced lightweight materials to demonstrate the feasibility of this approach. STO III.G.1 supports development of a 22-ton Composite Armored Vehicle.

By 1996, structural design optimization techniques will be demonstrated. By 1999, simulation tools for composite material design and fabrication will be developed and validated. By 2000, IPPD will be used to develop a virtual manufacturing facility for composite structures. IPPD will result in a 33 percent reduction in vehicle development time and costs by 2000.

Through the use of lightweight materials, a combat vehicle chassis with a 33 percent reduced structural weight and a turret with a 24 percent weight reduction will be demonstrated by 2000. A fully functional vehicle with a 33 percent weight reduction will be demonstrated by 2006.

Major Technical Challenges

Use of composite materials and/or titanium as the primary structure in the combat vehicle chassis is new. Composite issues include durability, producibility, and repairability. Titanium has yet to be used on combat vehicles because of cost. Through an IPPD approach, all issues relating to the successful fielding of a combat vehicle, including cost, are addressed.

c. Integrated Survivability

Goals and Time Frames

This technology effort's objectives are to provide an integrated survivability solution that will protect ground combat vehicles from a proliferation of advanced threats. With ever changing threats and missions, the integrated survivability approach allows for flexibility in meeting mission needs. Detection avoidance, hit avoidance, and advanced protection technologies will be developed and integrated to enhance overall vehicle survivability.

This technology effort's objectives are to provide an integrated survivability solution that will protect ground combat vehicles from a proliferation of advanced threats. With ever changing threats and missions, the integrated survivability approach allows for flexibility in meeting mission needs. *Detection avoidance, hit avoidance,* and advanced protection technologies will be developed and integrated to enhance overall vehicle survivability.

Detection avoidance technologies include signature management and visual perception. Signature management efforts are focused on exploring vehicle signatures in the visual, thermal, radar, acoustic, and seismic areas and in various atmospheric conditions. Visual signature analysis will be enhanced through the use of visual models and laboratory experimentation of visual perception.

Hit avoidance technologies protect ground vehicles through the use of sensors and countermeasures. The sensors detect incoming threats and the countermeasures confuse or physically disrupt incoming threats. The Army is developing electronic countermeasure and sensing technologies to defeat current and future smart munitions. *By the end of 1997, active protection against smart horizontal munitions and countermeasures to defeat laser designated threats will be demonstrated; competing active protection technologies will be evaluated.* By 2000, a reduction in hit probability from the current 0.8–0.9 to 0.2 will be demonstrated.

Advanced protection technologies include the development of armor, laser protection work, and the exploration of non-ozone depleting substances to use for fire suppression. Armor plays a synergistic role with detection and hit avoidance on the modern battlefield. It provides the last line of defense. Armor can also protect against mine blasts and, by 2000, a mine survivable contingency peacekeeping vehicle will be demonstrated. Laser protection technologies are being developed to prevent blinding and eye damage of vehicle crews due to the use of lasers on the battlefield. Laser protection for all unity vision devices (STO #IV.S.07) will provide eye safety against enemy agile wavelength laser threats. The work in this area is twofold. First, non-linear optical materials developed commercially and at other DoD agencies will be characterized. Second, work to design and integrate a retrofittable optical surveillance system is being performed. Finally, in the area of advanced protection technologies, is the exploration of non-ozone depleting substances for fire suppression use. Work in this area will focus on demonstrating environmentally and toxicological acceptable replacements for Halon 1301 in fire suppression systems in crew occupied compartments of ground combat vehicles.

None of the aforementioned technologies alone can ensure survivability and mission flexibility. The integrated survivability approach ensures the proper mix of these technologies so that survivability and mission flexibility may be achieved.

Major Technical Challenges

Cost of the currently identified technologies are prohibitive for application to all vehicles. Many of these technologies have significant weight, volume, electrical power, and thermal loading requirements. Insertion of these technologies into fielded systems can be costly and time consuming.

d. Mobility

Goals and Time Frames

The mobility technology effort focuses on the "move" function of tracked and wheeled land combat vehicles. Mobility components for ground vehicles include the suspension, track wheels, engine, transmission, and fuels/lubricants.

To increase both the survivability and lethality of combat vehicles, technology plans are in place to nearly double the cross-country performance of combat vehicles over the Abrams/Bradley baseline by 2005. Military vehicle cross-country speed is usually limited by the driver's ability to tolerate the vibration energy transmitted from the suspension. Increasing on-board computational capability has made it possible to actively control both the spring and damping rates of "active" suspension systems, reducing structural vibration and shock.

The vehicle track accounts for 8 to 10 percent of the gross vehicle weight, presents a costly maintenance burden, and emits a significant acoustic signature. Quiet, lightweight band track is being adapted from the commercial market. Demonstrations of lightweight band track for 20-ton vehicles will occur by 1997.

While all vehicles except the tank and its derivatives use diesel engines, they all operate below their commercial horsepower ratings. By 2000, military diesel engine power density will increase by 33 percent through application of advanced fuel injection systems, high efficiency, broad range turbo machinery, and low heat rejection techniques.

Power requirements of combat vehicles are increasing rapidly to accomplish the goals of advanced weapons, survivability systems, and increased mobility. Because electrical power will be shared among propulsion, survivability, lethality, and auxiliary systems, energy management becomes a new driver in combat vehicle design. Electric drive systems allow real-time control of power distribution without the addition of redundant power systems. With electric drive, the engine, transmission, and output to the wheels/drive sprockets no longer have to be co-located, allowing greater flexibility in overall vehicle design. Hybrid electric drive versions of the M113, Bradley, and HMMWV will be demonstrated in 1997.

Major Technical Challenges

For electric drives, major challenges include the requirements to greatly increase the available auxiliary power, reduce the cooling system size by a factor of six, and reduce the total transmission volume by 30 percent.

For advanced track systems, the major challenge is to extend lightweight conventional track durability while reducing operational and support costs.

For fuels and lubes, the major challenge is to define performance tradeoffs for development of a single engine/powertrain lubricant, as a single lubricant would greatly decrease operational and support requirements.

e. Intravehicular Electronics Suite

Goals and Time Frames

The goal of this subarea is to develop a standardized framework within which to integrate technologies for electronic embedded vehicular weapons system. This will enable current and future ground vehicles to maintain superior combat effectiveness and to function effectively on the digital battlefield. The Intravehicular Electronics Suite has two primary technological focuses: the integration of the electronics into the vehicle, and the natural and seamless interconnection of crew with the electronics.

The Intravehicular Electronics Suite will provide the necessary integration flexibility to support the wide-ranging battlefield digitization functionality in vehicular weapon systems over the next decade. It is the first step toward creating a general purpose electronic platform for multipurpose sensors and sensor fusion. Through a balance of flexibility and rigidity, the system will allow for improvement in the performance and capability of the system. This improvement can be incremental or continuous, adding or upgrading the processors, memory, or software functionality necessary to keep pace with the demands of the battlefield. This reliance on commercial, open standards for this electronics suite, coupled with the ability to continuously improve the system, will delay obsolescence of the system. The Army will be able to utilize state-of-the-art hardware at any time from multiple sources with minimal risk or development.

To achieve the first focus, future ground vehicles and upgrades to the current fleet will have to comply with both the Army's C41 Technical Architecture for integration with the Force XXI battlefield and the VETRONICS Open Systems Architecture (VOSA) for vehicular integration. The cornerstone of the VOSA is the utilization of commercial, open standards wherever possible to provide structured flexibility within the weapon system. This structure will allow for substantial reductions in development time and cost. In addition, the flexibility of systems built to the VOSA guidelines will enable the Army to utilize a continuous product improvement methodology, instead of the more expensive block-upgrade approach, to maintain weapon system capabilities at a near state-of-the-art level.

The structure and flexibility of the VOSA will also contribute to attaining the second focus, interconnecting the soldier with the electronics. Research into Soldier-Machine Interface (SMI) design and specialized electronics hardware will result in new and innovative designs for implementation into vehicular electronics systems. The VETRONICS System Integration Lab (VSIL), the first system built to the VOSA guidelines, will provide a mechanism to validate both architecture performance and SMI implementation. The VSIL, scheduled for completion in 1997, will validate the architecture performance and interoperability of a VOSA system. By 2000, the VOSA will be operational within on-vehicle demonstration platforms.

This total system integration will increase the efficiency of the weapon system by providing synergism among all elements of the vehicle system. The net effect of this synergism should be a dramatic increase in combat effectiveness with a reduced crew workload.

Major Technical Challenges

Specific technical challenges include:

- Electronic integration "techniques" that are scalable to many platforms.
- Real-time distribution of battlefield information within a vehicle.
- Reduction of system development time and cost.
- Reduction of system integration time and cost.

In the IntraVehicular Electronics Suite subarea, validated crew performance of advanced crew station through warfighter experimentation. Defined Weapon System Technical Architecture (WSTA) portion of the Army C4I Technical Architecture. This architecture will be implemented across ground vehicle, missile, artillery, and dismounted soldier domains.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Ground Vehicles is shown in Table IV-S-1.

Table IV-S-1. Technical Objectives for Ground Vehicles

Technology Subarea	Near-Term FY97-98	Mid-Term FY99-03	Far-Term FY04-12
Systems Integration	• Validate virtual prototyping process. • Develop vehicle concepts representing superior revolutionary battlefield technologies utilizing the Virtual Prototyping process. • Demonstrate combat effectiveness of ground vehicle concepts via development of enhanced constructive simulation and new virtual simulation tools. • Identify clear science and technology lethality improvement plan for the mounted force. • OCRs supported: BC 01, 09, 11, 18; CSS 01, 04, 17, 21; DSA 01, 05, 14; DBS 23; MTD 01, 03, 04, 07, 08, 15; EEL 05, 11, 12.	• Demonstrate through Advanced Warfighting experiment a 50% reduced vehicle crew. • Test ATDs and TDs to verify lethality performance improvements. • OCRs supported: BC 01, 09, 11, 18; CSS 01, 04, 17, 21; DSA 01, 05, 14; MTD 01, 02, 03, 07, 15, 20; EEL 05, 08, 13, 16.	• Validate integration of the Future Combat System in the Systems Integration Laboratory • Integrate commercial electronic architecture across multiple vehicle platforms. • Transition science and technology to current and future mounted force. • OCRs supported: BC 01, 02, 03, 04, 05, 07, 10, 18, 27; CSS 01, 14, 17, 18, 21; DSA 01, 06, 09, 14; DBS 17, 23; MTD 01, 02, 03, 04; EEL 01, 04, 05, 13, 16, 21.
Vehicle Chassis and Turret	• Full-Scale Blast test of Mine Survivable Vehicle. • Baseline IPPD Model developed. • Demonstrate composite material design optimization techniques. • Demonstrate and validate improved performance of the Composite Armored Vehicle ATD • OCRs supported: CSS 17, 18, 21; DSA 21, 22; DBS 09; MTD 03, 07, 08, 10; EEL 10, 16.	• Use IPPD to develop Virtual Factory of fabrication of ground vehicle composite materials • Develop/validate simulation tools for composite material design and fabrication. • OCRs supported: CSS 18, 21; MTD 01, 02, 03, 04, 07, 15, 20; EEL 05, 08, 13, 16.	• Develop and demonstrate the Heavy Combat Ground Vehicle with gross vehicle weight savings of 33% over the Abrahms/Bradley baseline. • OCRs supported: CSS 21; DSA 21, 22; DBS 09; MTD 03, 08, 10; EEL 10 16.
Integrated Survivability	• Demonstrate active protection against smart munitions. • Demonstrate countermeasures against laser-guided munitions. • Reduce visual & near IR signature by 25%. • Reduce EW hardware emitted thermal & radar signatures by 25%. • Reduce hit probability from 0.8–0.9 to 0.2. • OCRs supported: BC 03, 05; CSS 21; DSA 12; DBS 13; MTD 07, 08, 10, 16; EEL 09.	• Reduce acoustic signature by 50%. • 40% weight savings of integrated signature management armor. • 35% weight reduction of heavy vehicle frontal armor. • OCRs supported: BC 03, 05; CSS 21; DSA 12; DBS 13; MTD 07, 08, 09, 10, 16.	• Develop and field test Ground Vehicle Air Defense system. • Integration of an optimized survivability package. • Demonstrate hit avoidance against a 21st century threat. • Reduce performance of enemy top attack munitions by 90%. • OCRs supported: BC 03, 05; CSS 21; DSA 12; DBS 13; MTD 07, 08, 09, 10, 16; EEL 09.
Mobility	• Demonstrate hybrid electric, Bradley, M113, and HMMWV Vehicles. • Demonstrate 100% service life increase for track rubber. • Demonstrate lightweight band-track for 30-ton vehicles. • OCRs supported: CSS 17; DSA 05; DBS 24; MTD 03, 04, 06, 07, 08, 10; EEL 16.	• Demonstrate high power density low heat rejection engine. • Demonstrate full active suspension—75% increase in cross-country speed. • Develop higher operating temperature power electronics. • OSRs supported: CSS 17, DSA 05; DBS 24; MTD 03, 04, 06, 07, 08, 10; EEL 16.	• Double cross-country performance. • Demonstrate integration of a 600-hp electric drive with an electric gun. • Develop, validate, and integrate electric Future Combat System mobility components. • OSRs supported: CSS 17, DSA 05; DBS 24; MTD 03, 04, 06, 07, 08, 10; EEL 16.

(Continued)

Table IV-S-1. Technical Objectives for Ground Vehicles (Continued)

Technology Subarea	Near-Term FY97-98	Mid-Term FY99-03	Far-Term FY04-12
Intravehicular Electronics Suite	• Validate architecture performance through simulation laboratory experiments. • Complete construction of VSIL. • OCRs supported: BC 01, 02, 03, 04, 05, 07, 11, 20, 23; CSS 01, 18; DSA 06, 07, 18, 19; DBS 01A, 18; MTD 12, 14, 15, 16, 17, 20; EEL 05, 11; TRD 01, 03, 05.	• Integration of open systems architecture into Scout Advanced Technology Demonstrator. • Integration of Crewman's Associate ATD crew station into simulation laboratory. • Through development of open architecture, reduce software development costs by 50%. • Demonstrate open systems architecture across multiple platforms. • Apply IPPD to electronics integration effort. • OCRs supported: BC 01, 02, 03, 04, 05, 07, 11, 20, 23; CSS 01, 18; DSA 06, 07, 18, 19; DBS 01A, 18; MTD 12, 14, 15, 16, 17, 20; EEL 05, 11; TRD 01, 03, 05.	• Integration of high-power of electronics into Future Combat System Technology Demonstrator • Upgrade Systems Integration Laboratory to high power electronics. • OCRs supported: BC 01, 02, 03, 04, 05, 07, 11, 20, 23; CSS 01, 18; DSA 06, 07, 18, 19; DBS 01A, 18; MTD 12, 14, 15, 16, 17, 20; EEL 05, 11; TRD 01, 03, 05.

T.

Manufacturing Science and Technology

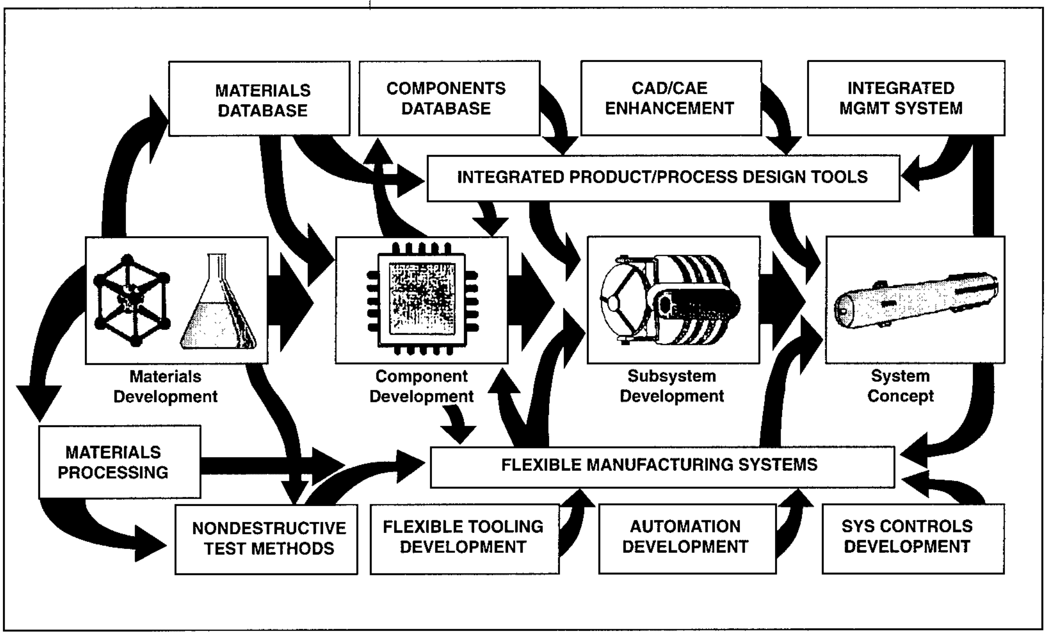
1. Scope

The Manufacturing Science and Technology (MS&T) area focuses on technologies that will enable the industrial base to produce reliable and affordable materiel for the soldier with enhanced performance parameters in a reduced cycle time. The technologies in MS&T include processing and fabrication, manufacturing engineering, production management, design engineering, enterprise integration, integrated product and process development, and flexible manufacturing systems capable of addressing both high and low volume dual-use production. The interrelationships between all these technologies are illustrated in Figure IV-T-1. MS&T addresses the needs of the soldier by deriving requirements from three thrusts: acquisition and sustainment driven needs, pervasive industrial base needs, and science and technology needs and opportunities. Potential projects based on these needs are prioritized according to their relevance to TRADOC Operational Capabilities Requirements (OCRs) and their significance to the successful attainment of Advanced Technology Demonstration (ATD) and Advanced Concept Technology Demonstration (ACTD) objectives.

The MS&T Program focuses on three subareas:

- Advanced Processing of metals, composites, and electronics with emphasis on the development and validation of new manufacturing processes for defense-essential materials, components, and systems. Project technologies include validated process models, embedded sensors and adaptive control systems for composites and electronics manufacturing, improved composites airframe manufacturing for advanced helicopters, improved manufacturing and testing for advanced cooled and uncooled FLIR sensors, computer automated manufacturing for precision optics, manufacturing of advanced battery technology, flexible manufacturing for millimeter wave transceivers, flexible manufacturing of missile seekers and assemblies, and agile production control.
- Manufacturing Engineering Support Tools encompass manufacturing technologies such as computer-aided design, engineering, and manufacturing; artificial intelligence tools for a broad range of manufacturing processes; design and analysis tools for assessing product producibility and manufacturability; rapid prototyping; control and interface research for component modeling and system integration and information infrastructure; industrial base modeling and production allocation for management of coordinated supply chain and surge production. This subarea is

Figure IV-T-1. Relationships Among Integrated Product/ Process Design Tools and Flexible Manufacturing Systems



focused on developing tools for early involvement of the manufacturing discipline in the requirements and design process of new technologies.

- Advanced Manufacturing Demonstrations for the application of world-class best manufacturing practices and procedures in a factory environment. These demonstrations are usually large scale, include the pertinent aspects of the enterprise, have specific goals, and are performed over a 2- to 4-year time period.

2. Rationale

Defense acquisition strategies reflect a significant reduction in weapon systems development and production programs. The emphasis within DoD and the Army continues to be on upgrading and modifying existing systems while continuing to support the underlying doctrine of developing technologically superior weapon systems. This environment requires new processing and fabrication technologies and new manufacturing philosophies (flexible, lean, agile) in order to economically produce a wide variety of products in lower volumes. Army MS&T must develop and transition the technologies required to make weapon systems affordable both during materiel production and over the system life cycle.

3. Technology Subareas

a. Advanced Processing

Goals and Time Frames

The Advanced Processing subarea focuses on processing science and technologies that will lead to the production of affordable components with consistent and reliable properties. Emphasis is on process maturation and the development of technologies that can be implemented to control manufacturing processes.

The Army is focusing on the following advanced processing technology efforts: development of manufacturing processes for 2nd Generation Infrared Focal Plane Arrays (IRFPAs)/Dewar/Cooler Assemblies (FY95-98) which provide technology capability for the Multisensor Aided Targeting Suite, Target Acquisition ATD, Hunter Sensor Suite ATD, and Rotorcraft Pilot's Associate ATD; development of automated testing (FY97) and development of manufacturing processes for Uncooled Infrared Technologies (FY97-00) which have the potential technology for insertion into the Generation II Soldier ATD and remote Sentry ATD; development of optical manufacturing processes for optics manufacturing for spherical lenses (FY98-05) which pervasively support a variety of ATDs that utilize optical components; demonstration of an Adaptive Process Controller for the Resin Transfer Molding process for airframe structures (FY96-99); fabrication of thick composite parts (FY97-99) and insitu sensors (Smartweave) which will impact the Composite Armored Vehicle (CAV) ATD.

Other pervasive efforts include demonstration of integrated workcells for missile and munitions seeker assemblies with associated process control systems (FY99); development of laser-based optical prototyping system for titanium parts (FY98); casting process for Beryllium Aluminum (FY97; development of micro electromechanical systems (FY98); development of processes associated with flexible continuous processing of propellants and explosives using a twin screw mixer/extruder (FY96-97); demonstration of advanced processing of solid thermoplastic elastomer gun propellants utilizing in-process rheology control (FY98); development of improved machining, grinding, and inspection processes for precision gears (FY97); development of processes to improve manufacturing of fiber-optic cables; development of coating systems for engine components; and development of advanced nonmetallic rechargeable battery with current application on SINCGARS radio.

Major Technical Challenges

The major technical challenges for improving processing and manufacturing technologies include increasing performance while decreasing size, weight, and life cycle cost.

Specific challenges:

- Implement in-process controls and improved manufacturing techniques that will reduce highly skilled labor, increase yields, and increase throughput for tri-Service 2nd Generation standard advanced IRFPAs/Dewars/Coolers assemblies.

- Improve testing and manufacturing techniques to reduce costs and increase throughput associated with large focal plane arrays.
- Develop an embedded sensor system to monitor the resin flow through a composite perform during the RTM process.
- Eliminate costly dies and molds for fabrication of prototype titanium components and reduce costs associated with precision machining of Beryllium Aluminum components and precision gears.
- Develop and implement reconfigurable workcells, multimissile tooling and test stations, material handling control, and process control techniques.
- Miniaturize electromechanical systems to reduce power requirements and weight of soldier portable systems.
- Control of the manufacturing process to facilitate real-time correction and reduce or eliminate post process inspection.
- Reverse engineering of legacy electronic systems to provide form, fit, and function for older weapon systems with today's production technologies.
- Develop safe, cost-effective, high quality equipment and processes for manufacture of energetic materials—propellants/explosives/pyrotechnics.
- Develop flexible manufacturing capability for prismatic cell packaging which will allow low cost manufacturing of a variety of nonmetallic rechargeable battery configurations.
- Develop coating techniques for turbine blades and shrouds to improve performance and reduce life cycle cost of turbine engines.

b. Manufacturing Engineering Support Tools

Goals and Time Frames

Manufacturing Engineering Support Tools are essential to improve design, process analysis, prototyping, and inspection processes for manufacturing components and systems. Current Army efforts include developing production engineering tools which will assess product producibility and manufacturability based upon analysis of CAD drawings (FY96); integrating rapid prototyping system with production engineering tools to reduce product development time (FY98-00); developing advanced integrated manufacturing for missile seekers and munitions (FY96–Far-Term); and using Integrated Product Process Development (IPPD) to develop processing technology and producibility strategies during the earliest stages of production development. This latter activity is supportive of the EFOGM ATD, and the PGMM, RFPI, and Precision/Rapid Counter-MRL ACTDs.

Major Technical Challenges

The major technical challenges for developing Manufacturing Engineering Support Tools include the development of design and analysis tools for assessing product producibility and manufacturability; developing rapid prototyping tools; and advancing manufacturing technologies such as CAD/CAM/CAE and inspection. Specific challenges include the following:

- Software environments capable of automatically transferring CAD drawings to machine shops and controlling the required equipment to produce a desired part.
- Cost Estimator Tools that provide economic analysis of fabricating a part based upon the output of a design analysis tool.
- Optimization of design vs. fabrication process to minimize cost and cycle time via the development of a virtual factory capable of modeling factory floor processes.
- Quality assessment and control through computer vision inspection.
- Order release mechanism for electronic assembly systems.

c. Advanced Manufacturing Demonstrations

Goals and Time Frames

The advanced manufacturing demonstrations incorporate best manufacturing practices and integrated product and process development to merge innovative concepts and manufacturing technology into a system-level approach to integrated manufacturing. Army MS&T is currently conducting an industrial base pilot demonstration using the Longbow Apache Fire

Control–Mast Mounted Assembly as the demonstration article (FY95-97). A Battlefield Manufacturing Center (BMC) demonstration is being planned for completion in FY99. The BMC would communicate repair needs from a deployed position to manufacturing engineers located elsewhere; the engineers would model the repair using CAD/CAM systems and transmit the repair instructions to machines in the field. A planned demonstration pilot for millimeter wave missile seekers (FY97-FY99) will provide for affordable/flexible manufacturing and design of these missile components.

Major Technical Challenges

The results and observations of industrial pilots indicate that implementation of enhanced business practices combined with technology insertion can significantly reduce cost, increase product quality, and ultimately develop the capability to produce product in a lot size of one. The major challenges associated with advanced industrial practices include identifying, adapting, and implementing best manufacturing practices; identifying and implementing the appropriate tools for IPPD; and incorporating the changes into an enterprise's culture.

4. Roadmap of Technology Objectives

The roadmap of technology objectives for Manufacturing Science and Technology is shown in Table IV-T-1.

Table IV-T-1. Technical Objectives for Manufacturing Science and Technology

Technology Subarea	Near-Term FY97-98	Mid-Term FY99-03	Far-Term FY04-12
Advanced Processing	• Reduce the cost of tri-Service 2nd Gen. Standard IRFPA/ Dewar/Cooler Assembly by 30% and implement in Army and DoD systems. • Reduce 20% manufacturing cost of precision gear by improving grinding, deburring, inspection processes. • Increase manufacturing process yield 50% for fiber-optic cables and harnesses. • Reduce optical components cost >20% for spherical lenses. • Use resin transfer molding for advanced airframe structures. • Develop noncontact nondestructive test method to permit 100% evaluation of detector elements in focal plane arrays. • Develop processes for 60% reduction in machining of Beryllium Aluminum components. • Reduce manufacturing time by 25% for missile seeker domes and windows. • Twin screw processing of energetic materials. • Process scale-up of chemical/ biological defense enzymes and antibodies. • OCRs supported: DBS 03, 07, 21; MTD 02, 11; DSA 01; EEL 08; BC 20.	• Center for electronic manufacturing for supporting current and future changes in defense and commercial industrial base. • Advanced non-metallic rechargeable batteries. • Smart micro device for application on ultra-compact antenna technology and system integration for rotorcraft and helicopters. • Safe, environmentally acceptable, agile manufacturing technologies for propellants, explosives, and pyrotechnics which provide the flexibility to meet future production needs. • Develop real-time controlled welding process to reduce weld time by 50% for complex engine components. • Develop optimal machining processes for high performance gear materials. • Develop manufacturing processes for Uncooled Thermal imaging processors and Advanced Focal Plane Arrays. • Fabricate advanced optical components such as aspherical lenses at >20% cost reduction. • Eliminate manual tooling fabrication for optics production. • Reduce thick composites fabrication cost for armored vehicles by 30% and labor by 50% using integrated process development. • Develop real-time processing tool to provide flow modeling database for highly reinforced composite materials. • Reduce manufacturing risk and provide defense essential capability for heat treat distortion of gears. • Demonstrate bi-directional thru-wafer optical interconnects for advanced missile processors. • Reduce the cost of biological stimulants. • OCRs supported: DBS 03, 07, 08; MTD 02, 03, 11; EEL 08.	• Reduce 50% cost of aircraft transmission capability to produce them from thermoplastic materials. • Develop coating techniques for turbine blades and shrouds to improve performance and reduce life cycle cost of turbine engines. • Reduce the cost of propellants, explosives, and pyrotechnics by at least 25%. • Develop manufacturing processes for Monolithic Multifunction, Multispectral Advanced Focal Plane Array sensor systems, Multispectral starting FPA sensor systems, and on-chip massive optical parallel processors. • Enhance manufacturing processes for photonics. • Develop advanced tooling for cylindrical and toroidal lenses. • Demonstrate an image control/ neural network system to facilitate automated inspection of electronic modules. • High energy selective hardening of precision gears. • Lower missile seeker manufacturing costs by >30%. • Establish center of excellence for biotechnology. • OCRs supported: DBS 03, 07; MTD 02, 11; DSA 01; BC 20.
Manufacturing Engineering Support Tools	• Improve producibility of early designs using quick turnaround cell software.	• Develop enterprise metadatabase that puts information in a global form available to local shells.	• Develop advanced integrated manufacturing technologies (to include desktop tools and virtual factories) using integrated product development for the missile sector.
Advanced Manufacturing Demonstrations	• Reduce costs with a 15% weight reduction using integrated composite manufacturing for advanced aircraft. • OCRs supported: DBS 08; MTD 03.	• Demonstration pilot for millimeter wave seekers for 40% reduction in concept to hardware cycle time.	• Affordable manufacturing of rotorcraft systems through the use of turboshaft engine and rotorcraft airframe pilots. • OCRs supported: MTD 04.

U. Modeling and Simulation

1. Scope

The Army Modeling and Simulation (M&S) technology program is focused on technology development in the three management domains: (1) Training, Exercise, and Military Operations (TEMO); (2) Advanced Concepts and Requirements Generation (ACR); and (3) Research, Development, and Acquisition (RDA). The first domain addresses the Army operational requirements to support Force XXI and beyond and other simulation applications, where interoperable, distributed simulations—live, constructive, and virtual—at geographically separated locations are connected to form highly realistic synthetic environments. The other two domains are concerned with the Army institutional requirements to develop, generate, project, and sustain the force. Complex and dynamic problems of requirements definition and analysis, science and technology, acquisition and prototyping, test and evaluation, production and logistics, training and readiness, and military operations must be simulated in the scale and resolution essential for the battlespace faster than real time.

M&S technology development is carried out throughout almost all budget activities, making a distinction of efforts by program elements dubious. Hence, this chapter focuses on those M&S technology developments that are customarily associated with 6.2 activities, but may not necessarily be carried out under 6.2 category funding.

2. Rationale

The Army Science Board 1991 Study on Army Simulation Strategy unequivocally conveyed the reality: "Increased automation of our forces and materiel, including its acquisition and operational utilization, provides the highest payoff potential as a force multiplier to offset the ongoing force reduction."

To optimally exploit the opportunities offered by the emerging automation technologies, the Army Science Board put forward the concept of the Electronic Battlefield (EBF). This concept has been adopted by the Army. The long-term objective of the EBF concept is to develop and implement a single, comprehensive system of synthetic environments for operational and technical simulation that can support combat development, system acquisition, developmental and operational test and evaluation, logistics, training, mission planning and rehearsal in Army specific and joint operations.

The near-term priority—establishment of the simulation infrastructure—is currently being addressed by the Army Digitization Office and the Force XXI initiative. To ensure timely M&S support, the Army has streamlined its M&S management by establishing the Army M&S General Officers Steering Committee co-chaired by the VCSA and AAE, the Army M&S Executive Council co-chaired by the DCSOPS and DUSA(OR), and the Model and Simulation Office. The latter oversees all major Army M&S activities through the three management domains.

3. Management Domains

The majority of M&S technology base developments support multiple domains. To captivate the Army M&S management structure but avoid repeating common technology developments at multiple places, the capability requirements to be provided by the technology base are summarized in the individual management domains, and the S&T programs that are needed to attain these capabilities on a timely basis are described in the M&S subareas of the Defense Technology Area Plan (DTAP) Information Systems and Technology area.

a. Training, Exercise, and Military Operations

Army M&S technology development in support of the Force XXI Combined Arms Training Strategy (CATS) is the responsibility of STRICOM and is discussed in Chapter VI. Technologies must be provided that will enable substantially expanded use of simulators and simulations to train the soldier in a seamless synthetic environment as part of crew drills, routine deployment exercises, and live fire exercises.

Army M&S technology base development in support of military operations is coordinated by CECOM. Technologies must be advanced that provide faster than real time interactive, predictive, continuous running simulations in support of dynamic automated planning and execution control systems to increase the tempo of operations of the integrated force and enable the most efficient use of all resources—mobility, power projection, operations, and people. The following elements are key: (1) a flexible, secure, and situation-dependent interaction of the users with the synthetic environment, supported by intelligent systems that emulate human-like thought processes, learn, and adapt to user needs and make optimal use of commercial operating systems, network protocols, and programming languages; (2) multimedia knowledge sharing and management throughout the operational hierarchy, including situational awareness and resource data bases; and (3) an open-ended design of the dynamic planning and execution control system architecture.

b. Advanced Concept and Requirements Generation

Army S&T in this domain mainly supports brigade and below echelon aspects of the tactical force and materiel modernization requirement analyses, while technology development in support for strategic, operational, and upper echelon tactical force analyses is addressed by DARPA. M&S technologies must be advanced that will foster the realistic simulation of structure, employment and tactics, dynamics, and performance of organizational and materiel unit building blocks in a combined arms environment with the level of details and fidelity, the parameter variations, and the statistical accuracy specified by analysis and concept definition requirements and within the action/response times of the interacting live simulation constituency.

c. Research, Development, and Acquisition

This domain provides the technology base for the two preceding domains and the acquisition of materiel. For the latter, technologies have to be advanced that will enable the embedment of the total technology development and materiel acquisition process, from cradle to grave, in a system of networked synthetic environments that can seamlessly be linked with each other and the other domains. This includes technology base development, concept formulation and evaluation, ATD, DEMVAL, EMD, production, upgrade, DEMIL, and associated processes such as T&E, OT&E, logistics support assessment, cost estimation, performance and cost trade-offs, scheduling, cost and progress monitoring, and program management.

4. Technology Subareas

M&S is an information technology subarea: Information is used to generate new knowledge from available knowledge via modeling and simulating logical interrelations. This is manifested in the 1996 DoD Defense Technology Area Plan (DTAP) where Decision Making, Modeling and Simulation, Information Management and Distribution, Seamless Communications, and Computing and Software Technology comprise one technology area—Information Systems and Technology (IST). To provide ASTMP-to-DTAP connectivity, the M&S structure of the DTAP-IST—Simulation Interconnection, Information, Representation, and Interface—is maintained and interrelated to the ASTMP technology areas.

a. Simulation Interconnection

This subarea is concerned with the architectural design, protocols and standards, multilevel security, survivability, interoperability among simulations at different levels of resolution, and common services (application gateways, databases, time and workload management, servers, and translators) to conduct collaborative simulations over the information network. The Army mainly relies on DARPA and on private enterprise for technology advancements. Army M&S S&T programs on information network architecture and infrastructure for distributed M&S are delineated in Sections G, Command, Control, and Communications, and H, Computing and Software.

Goals and Time Frames

The goal is to provide interoperability for on-demand synthetic environments. This includes a high level architecture (HLA) which governs the synergistic formation and evolution of individual simulation infrastructures—live, constructive, virtual—and the systems and subsystems and simulation management. The architecture must enable a user friendly, intelligent, object-oriented, graphical environment. A prototype HLA should evolve within the next 2 years, giving impetus to the development of cost-effective methods for VV&A and ensuring military utility of the evolving HLA and the networked synthetic environments by 2005. Network accessibility and portability of existing data bases across all environmental domains and automatic multilevel exchange of multimedia information should become available by the end of this decade. Very large scale distributed simulation with adaptive, dynamic network resource allocation and distributed multimedia knowledge sharing at all classification levels will be possible for all three domains by the end of the next decade.

The Army, through STRICOM, has DoD responsibility for DIS standards and protocols and, thus, plays a major part in their development. Until the DoD synthetic environment technical reference model becomes available (FY00), building blocks will rely on DIS-based protocols between simulation infrastructures to supply the functional network control and management. DIS-related programs are contained in Chapter VI.

Major Technical Challenges

Algorithms, models, and associated software, and even data bases, lack DIS connectivity and real-time information processing capability, and the needed HLA is still evolving. The unavailability of mathematical algorithms to automate the conversion of discipline-specific simulation systems and subsystems for use in synthetic environments on a heterogeneous communications and computation network is a technical barrier.

b. Simulation Information

This subarea addresses modeling of mission space, mission tasks, strategy, tactics, intelligent systems emulating human decision making processes, and optimal resource utilization.

Mission Planning, Rehearsal, and Execution Control Management

These tasks are inherently scenario-dependent, multistep, multifaceted, hierarchical processes involving complex evaluations at different information aggregate levels. Current planning capability is cumbersome, manpower intensive, time consuming, and judgmental. The infrastructure to support rapid automated mission planning, simulation-embedded mission rehearsal, and real-time simulation-aided execution management aids is evolving through the digitization of the battlespace. Missing are the computational methods, artificial intelligence algorithms, architecture, logical relations, and associated software that are necessary for the formulation and evaluation of scenario-dependent, complex military situations in the context of higher level command and control instructions and within the operational tempo. While DARPA is the major player in advancing technologies for simulation-based tactical decision making, Army S&T concentrates on their application and filling the gaps.

Goals and Time Frame

The long-term goal of this subarea is to provide the synthetic environments for automation-assisted C2 throughout the evolving C4I infrastructure. While near-term emphasis is on information overload reduction, mid-term emphasis is on mission and route planning for lower echelon assets and the aggregation of the individual plans into integrated company and battalion level plans. This also includes mission sustainment (e.g., logistics, maintenance and repair, soldier services).

Computer Generated Forces (CGF) requires the representation of human (soldier) behaviors for the realistic simulation of system performance. Individual soldiers, groups of soldiers (units/crews), single weapons platforms, and units of platforms must be simulated as aggregated and disaggregated entities. The goal is to represent adaptive, interactive, "intelligent" behaviors of soldiers, units, platforms and smart weapons in variable scale realistic synthetic environments. The primary development and application of CGF for the Army is promulgated in the evolution of Modular Semi-Automated Forces (ModSAF) through the cooperative efforts of AMC and ARPA. Ongoing Army S&T includes modeling of systems and subsystems in computer software, interaction among the models and with other components of the simulation environment, and integration to support near- and mid-term operational requirements.

Computation-aided operational planning requires algorithms that translate military command and control instructions into computer language, integrate these with battlespace environment, battlespace situation awareness information, and mission specific doctrines. Predictive, networked, simulation-based planning will be possible within the next 15 years.

Computation-aided mission rehearsal requires the same technologies and data bases as mission planning as well as virtual reality. Within the next 15 years, technologies will support implementation of materiel embedded training, where individual units and their aggregates are fully immersed in synthetic environments, with horizontal and vertical synchronization throughout the operational forces partaking in the rehearsal using in-place equipment.

In order to increase automation in operational execution control management, artificial intelligence technologies are needed that speed up and improve decision, command and control, and information flow processes based on situation and resource knowledge. This includes technologies for automated revision of mission and route plans for the fighting units as well as their support, area-controlled, hierarchical information management over combat communications networks, and application-tailored information display and network interface. Near-term emphasis is on providing information management technologies tailored to the needs of the digitized battlefield infrastructure. Model and computation optimization technologies and use of scalable massively parallel processors will enable dynamic, simulation-assisted, C4I node execution control management within the next 10 years, followed 5 years later by adaptive management that is fully coordinated throughout the battlespace.

Major Technical Challenges

Technologies are not yet available to enable fast and situation-adaptive operational planning with optimal use of resources throughout the hierarchical task force structure, including support elements. Of particular challenge are operational rehearsal (and training) of force components in a virtual environment that projects the most likely battlespace situation and operational execution, with intelligent systems-aided command and control oversight. Both must be able to quickly adjust mission plans to changing situations. Algorithms must be advanced for integrating the individual synthetic environments (e.g., for elements of the operating forces and their support) into an aggregate system and for scaling the computer-generated forces and support from entity level through any level of hierarchical echelon, while preserving the dynamics and behavioral aspects of aggregation and disaggregation. Also, realistic/trustworthy accounting and forecasting of the state and ability of human resources—ours as well as foe's—are necessary. This includes the effect of battlefield stress on human performance and casualty and incapacitation from battlefield hazards.

Materiel Acquisition

DoD policy requires that all new major system developments be carried out embedded in open architecture simulations, using DoD-specific and COTS engineering, software engineering, and life cycle management tools to reduce acquisition time and life cycle cost. M&S science and technology in support of engineering designs and analyses is an intrinsic part of the non-information technology areas and described in that discussion. Development of technologies to integrate individual M&S software for system design and manage the engineering process is mainly commerce driven, with active participation of Army RDECs in their area of acquisition support responsibility.

Goals and Time Frames

The long-term goal is to establish a capability to produce synthetic prototypes of systems with a complete electronic documentation of the products, engineering models, and software tools used, manufacturing and assembling instructions, and performance.

In support of ACR, M&S technologies are being developed that will provide, within the next decade, the capability to remotely access expert repositories at RDECs, Battle Labs, and other organizations including industry; search for and retrieve operational and technical models and data bases pertinent to the concept to be evaluated; and integrate this information, in a synthetic environment, into candidate systems with operational performance and technology exploitation optimized to the available acquisition resources. Rudimental systems are already in place to integrate realistic synthetic system mock-ups (virtual prototypes) into operational simulation environments via DIS.

In the materiel development, engineering, and production area, technologies are required that allow highly automated utilization of engineering models in the design of components and their integration into a system, employing concurrent, automated software configuration management with or without physical simulators in the loop, in support of and tailored to the development of specific materiel or ATDs in both the tactical and the strategic arena. Considerable progress has been made by the Army RDECs, AF Manufacturing Technology Directorate, DARPA, NIST, and other organizations in developing and demonstrating virtual prototyping and manufacturing for application specific problems. These technology advances are now being exploited in various Army simulation and modeling projects to systematically formulate the process of designing and building simulation substructures in a modular fashion with adaptable, flexible interfaces. Emphasis is on simulating the manufacturing process of materials, their machining into components, and their assembly into virtual prototypes. The Army S&T programs in support of this area are detailed in Sections P, Materials, Processes and Structures, and T, Manufacturing Sciences and Technology.

Testing and evaluation of the design and performance of components, subsystems, and systems are an integral part of the materiel acquisition process. Even though physical simulators are increasingly used for components hardware and software in-the-loop testing, the current T&E methodologies are nevertheless labor, time, and cost intensive and do not support the concept of rapidly configurational prototyping through synthetic environments. The Virtual Proving Ground, now in development by TECOM, will increase the synthetic environment capability for components simulation; shortening the human in-the-loop design, test, and fix cycle; and enable networking of T&E, OT&E, and other data bases. Ongoing S&T work supports the development of a flexible open architecture that will seamlessly link constructive, virtual, and live T&E simulations.

Major Technical Challenges

Apart from technologies for the synthetic operational environments, the development, engineering, and manufacturing M&S technologies and tools used in the acquisition process are basically the same as for similar commercial products. Most of the tools are stand-alone software packages lacking open architecture; hence, software and repository integration into domain-specific synthetic environments and their embedment into an integrated, networked acquisition process and management environment are a tedious and difficult endeavor. The technical simulation models in use today are mainly general scientific and engineering analysis computer programs for application-specific system components and physical processes. The majority lack rapid interconnectivity with each other and with operational M&S and require software reengineering for efficient use on parallel processors. To replace the current prototyping/testing approach with virtual prototyping, and thereby attain the potential large savings in cost and development time, the evolving methodologies—first principle models, performance data/prediction, and system simulation—must first undergo a rigorous VV&A process.

c. Simulation Representation

This subarea is concerned with technologies that will enable, within the time of operational decision cycles, the generation and the realistic, high-fidelity synthetic representation of the prevailing physical environment, natural and man-made (e.g., terrain, hydrography, atmosphere, vegetation, buildings), the materiel and humans operating in it, and their interactions with each other. The M&S programs that constitute the prevailing physical environment and enable its display are described in Sections M, Battlespace Environments, and N, Human-Systems Interface.

Goals and Time Frames

The synthetic physical environment must be accurate, realistic, and capable of rapid updating to provide a sense of normal time flow during a simulation process across a wide variety of M&S systems. By the end of this decade, the fundamental technologies necessary for integrating maps from distributed environmental data bases, information on current weather and from battlefield situation awareness, and simulation-based assessments of tactical movements put forward by C4I node staff into an aggregate dynamic environment and presenting it into mission specific spatiotemporal 3-D scene projection will be developed for virtual sand table applications. Highly interactive, high fidelity environment and force representations will be possible within 15 years. Efforts are underway to automate the generation of electronic environment data bases and to increase their spatial resolution to DTED level II (10m) is in progress. This data base will comprise digital maps for terrain, soils, roads, drainage, foliage and other environment characteristics. High fidelity, full-spectrum weather models for the evolution of the environment and its effect on individual system performance should be realizable within the next decade (FY05). Realistic human/group behavior representation under battlefield conditions will be possible within 10 to 15 years.

Major Technical Challenges

All sensors, including humans, are impacted by environmental conditions. Unavailability of valid environmental data, in the resolution required for each combat system, is a major barrier to achieve realistic simulation. Multimedia knowledge sharing of environmental information between distributed heterogeneous data bases is still unresolved. The lack of mathematical algorithms and corresponding software to represent a "real" physical environment represents a major barrier. To overcome this barrier we need to reduce time and cost of data base development and harness computational performance for dynamic environmental representation as well as to maintain consistency across models of varying resolution.

The lower echelon combat C4I nodes will be overloaded with information and, thus, may be unable to make all the logical decisions necessary to effectively implement higher echelon command and control. Intelligent systems with automated reasoning emulating the human thought process must be advanced that provide battlefield (human) decision makers, especially in stressful environments, with information that they need when they need it without overwhelming them.

d. Simulation Interface

This subarea addresses the development of technologies that will enable quick and responsive interface between the human and synthetic environments and realistic dynamic representation of systems in synthetic environments and of synthetic forces to the human.

Goals and Time Frames

The goal is to provide the algorithms and associated software that connect the synthetic environment with the machine hardware and firmware that interfaces with the human and will allow the soldier to interact with the machine in human-like fashion and without distracting from the task to be performed. Human-like interface between the synthetic environment and soldiers will be possible within 10 years; full immersion of the soldiers for rehearsal and as part of the operational execution, within 15 years.

Major Technical Challenges

Algorithms are needed to characterize vision and nonvision sensory to support the development of highly flexible and rapidly reconfigurable user interface stations which serve as input and feedback devices to the simulation network. Also, hardware and software are needed for high resolution, real-time scene generation.

A barrier to human-like interface with the synthetic environment is the lack of understanding on how human language interacts with information systems. Connected speech systems with increasing natural language interpretation and voice recognition that can be quickly trained for different voices are appearing. Because of commercial market applicability, industry and dual-use technology advancement programs are already addressing the barrier and will provide the needed speech recognition, parsing, and dialog management technology base, enabling the Army S&T to concentrate on military domain-specific applications.

5. Roadmap of Technology Objectives

The roadmap of technology objectives for the M&S Computer Generated Forces domain is shown in Table IV-U-1.

Table IV-U-1. Technical Objectives for Modeling and Simulation

Technology Subarea	Near-Term FY 97-98	Mid-Term FY 99-03	Far-Term FY 04-12
Interconnection	• DIS-based protocols and interfaces for M&S infrastructures. • Prototype high level architectures. • Initial software reuse via domain-specific architectures and interfaces. • OCRs supported: BV01, 02, 08, 09, 12, 13, 22, 23; CSS01, 09, 10, 11,18, 22, 24; DAS08, 10, 15, 19, 20; DBS03, 13, 14, 17, 19, 20; MTD01, 02, 05, 07, 12, 14, 15, 16, 17, 18, 20; EEL11, 12,15, 21, 22,24; TRD01, 05	• Tools/models with connectivity and real-time information processing. • Cost-effective VV&A methodology for networked synthetic environments. • Data base accessibility and portability across network with multimedia information exchange. • Open architecture softwa re engineering environment framework with process support. • OCRs supported: BC01, 02, 08, 09, 12, 13, 22, 23; CSS01, 08, 09, 10, 11, 18, 22, 24; DSA08, 10, 15, 19, 20; DBS03, 13, 14, 17, 19, 20; MTD01, 02, 05, 07, 12, 14, 17, 19, 20; MTD01, 02, 05, 07, 12, 14, 15, 16, 17, 18, 20; EEL11, 12, 15, 21, 22, 24; TRD01, 05	• Architecture and interface codification and validation. • Very large distributed simulations with adaptive network resource allocations and multimedia knowledge sharing. • Standard, automated linked substructure-system-subsystem descriptions based on functional and physical features. • OCRs supported: BC01, 02, 08, 09, 12, 13, 22, 23; CSS01, 08, 09, 10, 11, 18, 22, 24; DSA08, 10, 15, 19, 20; DBS03, 13, 14, 17, 19, 20; MTD01, 02, 05, 07, 12, 14, 15, 16, 17, 18, 20; EEL11, 12, 15, 22, 24; TRD01, 05
Information	• Methods to reduce information overload at C4I nodes. • Extensive AI planning and decision support for Computer Generated Forces. • Software technology for adaptable, reliable systems (STARS). • OCRs supported: BC01, 03, 04, 07, 10, 12, 16, 17, 21, 22, 23; DSA09, 16, 17, 18; DSB03, 13, 14, 18, 20; MTD01, 02, 14, 15, 16, 17, 18, 20; EEL11, 12, 15, 21, 22, 24; TRD01, 02, 03, 05	• Automated mission and route planning for lower echelons. • Scalable object-oriented database management and information models. • Algorithms/tools for modular design of S&M sub-structures with adaptable, flexible interfaces. • OCRs supported: BC01, 03, 04, 07, 10, 12, 16, 17, 19, 20, 21, 22, 23; CSS01, 05, 08, 09, 10, 11, 18, 22, 23, 24; DSA06, 08, 09, 16, 17, 18; DSB03, 14, 18, 19, 20; MTD01, 02, 05, 07, 12, 14, 15, 16, 17, 18, 20; EEL11, 12, 15, 21, 22, 24; TRD01, 02, 03, 05	• Predictive, networked, simulation-based planning and C2 management. • Adaptive, dynamic resource allocation for very large scale distributed simulation. • Concurrent analyses of products and processes for prototyping and manufacturing by distribution teams. • OCRs supported: BC01, 03, 04, 07, 10, 12, 16, 17, 19, 20, 21, 22, 23; CSS01, 05, 08, 09, 10, 11, 18, 22, 23, 24; DSA06, 08, 09, 16, 17, 18; DSB03, 14, 18, 19, 20; MTD01, 02, 05, 07, 12, 14, 15, 16, 17, 18, 19, 20; EEL11, 12, 15, 21, 22, 24; TRD01, 02, 03, 05
Representation	• High resolution, real-time scene generation. • Automated generation of electronic environment data bases (maps). • BC04, 05, 12, 23; DSA07; MTD02, 14, 15, 16, 17, 18, 19, 20; EEL11, 21, 22, 24; TRD01, 05	• High resolution, real-time infrared/ multisensor scene generation. • Mission specific, spatio-temporal scene projection of aggregate dynamic battlespace environment. • OCRs supported: BC04, 05, 07, 12, 23; CSS01; DSA07; DSB13, 14, 17, 19; MTD01, 02, 05, 07, 14, 15, 16, 17, 18, 19, 20; EEL11, 21, 22, 24; TRD01, 05	• High fidelity, full spectrum weather evolution models. • Highly interactive high-fidelity force and environment projection. • Realistic human/group behavior. • OCRs supported: BC04, 05, 07, 12, 23; CSS01, 18, 24; DSA07; DSB13, 14, 17, 19; MTD01, 02, 05, 07, 14, 15, 16, 17, 18, 19, 20; EEL11, 21, 22, 24; TRD01, 05
Interfaces	• High resolution, wide FOV night vision. • OCRs supported: BC04, 07, 12, 23; CSS01, 08, 09, 10, 11, 18, 22, 24; DSB03, 13, 14, 17, 19; MTD01, 02, 05, 07, 14, 15, 16, 17, 18, 19, 20; EEL11, 21, 22, 24; TRD01, 03, 05	• 3-D volumetric view with 3-D audio. • Color helmet display. • OCRs supported: BC04, 07, 12, 23; CSS01, 08, 09, 10, 11, 18, 22, 24; DSB03, 13, 14, 17, 19; MTD01, 02, 05, 07, 14, 15, 16, 17, 18, 19, 20; EEL11, 21, 22, 24; TRD01, 03, 05	• Human-like interaction with synthetic environment. • Full immersion into synthetic environment. • OCRs supported: BC04, 07, 11, 12, 23; CSS01, 08, 09, 10, 11, 18, 22, 24; DSB03, 13, 14, 17, 19; MTD01, 02, 05, 07, 12, 14, 15, 16, 17, 18, 19, 20; EEL11, 21, 22, 24; TRD01, 03, 05

CHAPTER V

Basic Research

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CHAPTER V

Basic Research

For I dipt into the future, far as human eye can see, saw the vision of the world, and all the wonder that would be.

Alfred, Lord Tennyson

A. Introduction

The Army is the full spectrum land warfighting force of the United States. In order to maintain the overmatching capability on which the U.S. depends, the Army needs to maintain its *investment in the fundamental research that is the "seed corn" for the technological discoveries and advancements* on which it relies. This is the role of basic research: to foster progress and innovations in niche areas (such as armor/anti-armor) or where the commercial incentive to invest is lacking due to limited markets (e.g., in military medicine to develop vaccines for tropical diseases); and to shape research and innovations in other areas to focus on issues related to Army applications/environments. In this way, the Army is able to develop or adapt the technology it needs for the ever-increasing variety of missions it faces. The Army's dependence on technology is increasing as it evolves toward smaller, lighter, more lethal forces that must accomplish the various missions required in a post-Cold War world. The investment made in basic research today will shape the future Army by providing the technological building blocks that will allow it to address imperatives emerging from future warfighting concepts (see Chapter II).

The program is managed and performed by a network of Army laboratories and centers. The Army Research Office (ARO) manages extramural programs through the University Single Investigator program and selected Centers of Excellence. The Army Research Laboratory (ARL) conducts in-house research, manages the Federated Laboratories, and supports several Centers of Excellence. The Medical Research & Materiel Command, Corps of Engineers, and Army Research Institute for the Behavioral and Social Sciences conduct a mixture of in-house and extramural research in their areas of interest. Finally, primarily through the In-house Laboratory Independent Research (ILIR) program, the Army Materiel Command Research, Development and Engineering Centers (RDECs) conduct a limited amount of basic research in relevant technical domains.

Without the scientific base developed by the Army laboratories, ARO, and the RDECs since World War II, the Army would hot have in its arsenal many of the technologies that now are taken for granted and that have been effectively utilized in many recent military operations around the world. The ultimate payoff of basic research is the translation of concepts into technological applications. Examples include the concept of inverted populations of excited quantum states translated into a laser; the use of fast mathematical procedures to calculate Fourier transforms for fire support systems; the design of advanced materials from basic principles to yield required properties and improved performance; and the incorporation of small, superfast electronic devices into systems.

Senior Army management is committed to a sustained research program that supports the Army's needs. To this end, the Army has structured a coherent basic research program that integrates in-house research in critical, Army-unique areas, with extramural research that leverages the power of academe and industry, focusing their capabilities on Army issues and interests through such programs as the Federated Laboratories, the Army Centers of Excellence, and single investigators.

The resulting science base provides the seeds for follow-on applied research (6.2) and, eventually, advanced technology developement (6.3) programs.

In planning the Army's Basic Research programs, the Army After Next (AAN) initiative of U.S. Army Training and Doctrine Command (TRADOC) provides additional focus for the overall program. AAN is an attempt to characterize the Army of 25 years in the future (~2020) and to begin to develop doctrinal concepts compatible with the Army of that era. AAN concepts include the types of technological capabilities that will underpin the Army's systems. Fostering the fundamental research that will enable these capabilities is a key role for the Army Basic Research program.

B. Strategy

The overarching strategy for fostering these future capabilities is portrayed in Figure V-1. Current Army modernization benefits from past investments in basic research. In the mid-term, products are expected from programs such as the Federated Laboratories that will benefit Force XXI and Army Vision 2010. In the long term, products of investments in key Strategic Research Objectives (SROs) (see below) and other basic research projects will influence the capabilities available to the Army After Next. Underpinning all of these programs are investments in each of the basic research areas, as defined in the *Department of Defense Basic Research Plan* (BRP).

The fundamental approach is to conduct focused research to develop and tailor knowledge and technologies to address *Army* needs. This includes both evolutionary research that advances the state-of-the-art and revolutionary concepts that provide the basis for breakthrough capabilities. At the heart of the program is a focus on conducting superior quality research across the spectrum of relevant technical disciplines. Wherever possible the Army leverages the investments of other Services and Agencies (e.g., DARPA). The strategy is based on making investments in Army-focused research to continue the evolutionary progress in key technical areas, and on tailoring unexpected innovations to Army applications, to meet emerging threats or to enhance future capabilities.

The Army investment in basic research is focused within the technical areas identified in the BRP. Within these areas, the investment is focused on Army-related issues, such as rotorcraft aerodynamics in the area of mechanics, and electrochemistry for high power density, compact power sources in the chemistry arena. The investment varies significantly across the technical areas, consistent with a conscious management strategy that takes into account several factors:

- Future Army concepts
- Emerging technical opportunities
- Ability to leverage investments via application in a wide variety of systems
- Investments that others are making (other Services, Defense Agencies, industry)

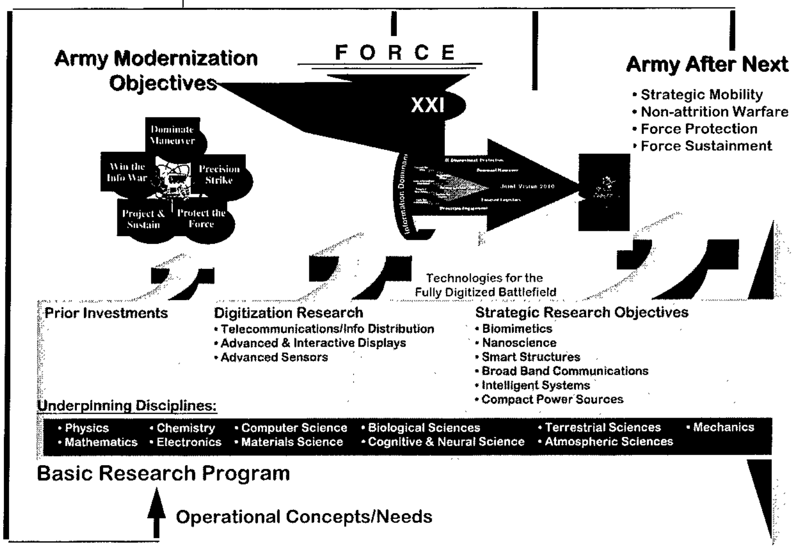


Figure V-1. Army Basic Research Strategy

- Need to maintain a capability in Army niche areas
- Program continuity.

Under the DoD *Basic Research Plan*, the Services have also identified six Strategic Research Objectives (SROs). These are high profile, long-range scientific areas of strong military relevance and high potential payoff. The current list of SROs includes:

- Biomimetics (novel synthetic materials through exploitation of nature's design principles)
- Nanoscience (control of devices with tens of angstroms precision)
- Smart Structures (dynamic control and response of complex systems)
- Broad Band Communications (flexible, high volume multi-media communications)
- Intelligent Systems (enable systems with ability to sense, analyze, learn, adapt and act)
- Compact Power Sources (Up to 10X improvement in portable batteries and fuel cells)

Although the relative investment in the SROs is small, the benefits are expected to be substantial. Each of these areas supports critical technologies of interest to the future Army.

The remainder of this chapter describes the extramural and intramural program components that contribute to the science base, followed by a survey of scientific research that is integrated across Army laboratories and centers and universities. Figure V-2 illustrates the flow of science through the Science and Technology continuum. Within this continuum there is constant feedback among the activities shown.

C. Extramural Program

The Army's basic research extramural program depends upon receiving top-quality proposals from academia and industry in response to published Army interests in the form of a Broad Agency Announcement (BAA). The process used by ARO to solicit, receive, review, and make awards based on these proposals is outlined in Figure V-3.

1. Centers of Excellence (COE)

Centers of Excellence continue to be an integral part of the Army's research investment strat-

Figure V-2. The Flow of Science Through the Army S&T Continuum

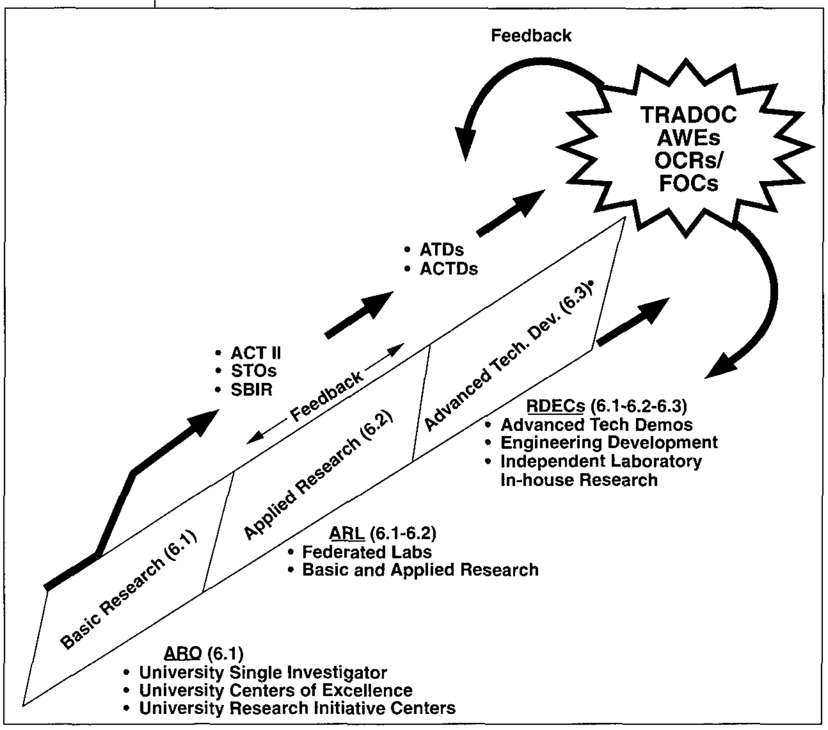
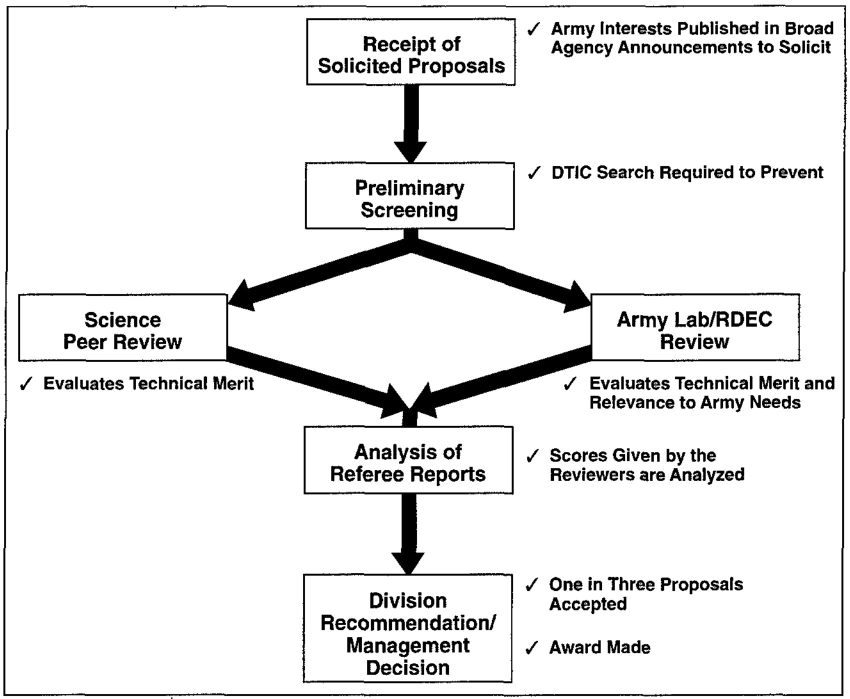


Figure V-3. Proposal Evaluation Process



egy, along with single investigator programs and Army laboratory research. Centers have proven to be effective in many applications-oriented projects, in areas such as rotary wing technology and electronics. Interdisciplinary research requires the joint efforts of many scientists and engineers and also often requires the use of expensive research instrumentation that is difficult for a single investigator to acquire. Center programs often couple the state-of-the-art research programs with broad-based graduate education programs to increase the supply of scientists and engineers in areas of Army importance.

The scientific research undertaken at each COE (and URI Center, see below) is dynamic and continuously reviewed, using various inputs for assessing the quality of the programs. These inputs include reviews by Executive Advisory Boards, representing high-level management of industrial and military organizations, and by Technical Advisory Councils, representing technical personnel from multi-Service organizations. Table V-1 illustrates the composition of a typical management and technical panel—in this particular case the Center for Intelligent Resin Transfer Molding for Integral Armor Applications.

Table V-1. An example of the Composition of an Executive Advisory Board and Technical Advisory Council for a Center of Excellence (here, the Center for Intelligent Resin Transfer Molding for Integral Armor Applications).

EXECUTIVE ADVISORY BOARD	TECHNICAL ADVISORY COUNCIL
Chairperson, Director, ARL Materials Directorate	Chairperson, ARO, Materials Science Division
ARO, Director, Materials Science Division	ARL, ST, Materials Directorate
NASA Langley, Director, Vehicle Structures Directorate	ARL, Scientist, Weapons Technology Directorate
AMCOM, Technical Director	Univ of Delaware, Scientist, Composites Mfg Sci Lab
TACOM, Technical Director	ERDEC, Scientist
Soldier Systems Command, NRDEC Director	TARDEC, Chief, Manufacturing Technology Branch
	McDonnell Douglas Missile Systems, Senior Group Manager-Composites
	Lockheed Martin, Manager, Advanced Programs
	United Defense LP Ground Systems, Manager Composite Structures

Army COEs are active in the research areas summarized in Table V-2. This table identifies each COE research program, provides a listing of participating universities, summarizes the scope of each program, and highlights future plans. Some of these centers have significant collaborative participation by historically Black colleges and universities (HBCUs) or Minority Institutions (MIs), a trend that the Army will be encouraging for future centers. In addition, industry will be encouraged to have greater participation in future Army COEs to leverage and synergize the investment in these collaborative efforts.

2. University Research Initiative (URI)

The Office of the Secretary of Defense continues to support a portfolio of programs characterized as the University Research Initiative. The Services share these funds, nominating and investing in subject areas and activities best correlated with their research and technology needs.

A series of five-year block grant URI programs, most funded at about $400,000 per year, concluded in FY96. Over 30 university groups performed research for the Army on topics under the broad research areas of biology, advanced propulsion, materials, high frequency microelectronics, elecro-optics, nanotech-nology, energy, manufacturing science, environmental sciences, and intelligent control systems.

Since FY94, each year has seen the start of several new 5-year multidisciplinary university research initiative (MURI) programs, most funded at about $1 million per year. The MURIs typically engage two or more science/engineering departments within the university, and sometimes other academic or industrial partners. Achievements not attainable through work in a single specialty are sought. For one example, new levels of intelligence in control of rotor blades requires the collaborative expertise of investigators in mathematics and computer science as well as in the fields of aerodynamics and aerostructures. For another example, successful experiments with extremely miniature turbine engines requires the collaborative expertise of investigators in propulsion as well as in the field of manufacturing science, and perhaps others. Table V-3 lists the Army MURI centers that have been established so far. An announcement for FY97 MURI programs (i.e., those that would terminate in FY2002) has been issued, and white papers are being received.

In addition to the above, the URI program supports two graduate science and engineering education programs: the National Defense Science and Engineering Graduate Fellowship Program and the Augmentation Awards for Science and Engineering Research Training Program. These programs comprise the bulk of the ongoing URI program. Other URI activities supported in FY96 included the Defense Experimental Program to Stimulate Competitive Research, the Infrastructure Support Program for HBCU/MIs, the Defense University Research Instrumentation Program, the Focused Research Initiative, and a Young Investigator Program.

In addition to the technical programs and resulting accomplishments of the URI and COE efforts, another major output from these Army-funded academic programs is the support and graduation of technical students—many of whom go on to work in Army laboratories or aligned industries.

3. Historically Black Colleges and Universities/Minority Institutions Program (HBCU/MI)

The Army Materiel Command (AMC) has set the pace for the DoD in programs for historically Black colleges and universities and minority institutions (HBCUs/MIs), which share the goal of strengthening the nation's HBCUs/MIs and enhancing their ability to prepare minority students for the future, highly competitive science- and technology-oriented marketplace.

AMC's broadly based program spans all of its laboratories and RDECs and includes a wide variety of initiatives. It includes programs for single investigator research, collaborative research, COEs, cooperative programs, and educational partnership agreements. In addition, the Army Research Office manages the DoD Infrastructure Support Program for HBCU/MI. This special program received approximately $15 million annually FY92–FY94, $21 million in FY95, and $13.5 million in FY96. To date, four Broad Agency Announcements involving Army, Navy, Air Force, and DARPA have been issued by ARO. The Services have awarded some $76 million to HBCUs and MIs

Table V-2. Army Centers of Excellence

RESEARCH AREAS/ PARTICIPATING UNIVERSITIES	SCOPE	FUTURE PLANS
SCIENTIFIC FOUNDATIONS OF IMAGE ANALYSIS Washington University	• Mathematical and algorithmic foundations of image science • Fundamental performance limits on ATR systems • Detection & recognition bounds	• Hibert Schmidt orientation bound • Orientation bounds for fused data
ADVANCED DISTRIBUTED SIMULATION Grambling State University	• Parallel and distributed computing • Heterogeneous multimedia database • Interactive graphics & visualization	• Advanced distributed simulation • Student training and education program • Enhance research infrastructure • Man-machine interface
TRAINING RESEARCH Morris Brown College	• Computer simulation • Memory strategy • Auditory enhancement • Critical decision making andteam performance	• Critical skills for trainers • Individual learning variables • Team performance characteristics • Cognitive conceptual behavior
INTELLIGENT RESIN TRANSFER MOLDING FOR INTEGRAL ARMOR APPLICATIONS Tuskegee University Consortium	• Intelligent resin transfer molding for integral armor applications • RTM process/manufacturing, sensing and control • New developments process modeling/phenolic resins • Bonding, repair and ballistic performance	• Smart weave and sensors in RTM • Virtual manufacturing of RTM process • Materials and process issues for integral armor • Performance modeling, simulations, and testing
SCIENCE EXCELLENCE Contra Costa	• Coordinated program to increase number of underrepresented graduates in science, mathematics, and engineering • Prescribed, sequential coursework • Mentoring and study groups • Internships and summer programs • Includes tuition and stipend • Outreach programs	• Enroll 250 students over 5-year period in science/math programs • Provide solid foundation in science and mathematics • Facilitate transfer to institutions awarding higher degrees • Encourage careers in science, engineering, and mathematics
SCIENCE, ENGINEERING & MATHEMATICS (SEM) Morehouse College	• Unifies multiple departments to enhance programs and increase under-represented graduates in SEM • Summer study, field trips • Mentoring/Research programs • Scholarship and outreach programs	• Enhance quality of science and mathematics instruction in secondary schools • Increase majors in SEM • Increase number of graduate students in SEM • Encourage careers in SEM
ELECTROCHEMICAL POWER Illinois Institute of Technology	• Electrochemistry • Advanced material systhesis • Manufacturing capability	• Lithium/metal oxide batteries • Nickel hydride batteries • Direct oxidation methanol fuel cells
AUTOMOTIVE University of Michigan	• Advanced ground vehicle simulation • Vehicle dynamics and structures • Advanced propulsion systems • Human/hardware interface	• Vehicle system optimization • Advanced vehicle controls • Ceramic engine optimization
MICROELECTRONICS University Of Maryland College Park	• Nanoelectronics and optoelectronics • Biological/chemical detection • Wideband gap electronics • Integrated terahertz devices	• Low power electronics • Individual biodetectors • High-speed signal processing • Blue-light emitting diodes/lasers
Johns Hopkins University	• Piezoelectronics and electrochemistry • Manufacturing science • Microelectro mechanics • High resolution display technology	• Affordable electronics • New battery concepts • New fuel cell concepts
COMPUTATIONAL GEOMETRY FOR INTELLIGENT SYSTEMS Consortium I - Brown/Johns Hopkins/Duke Consortium II - Univ Penn/ Stanford Univ	• Geometric computing • Algorithmic design & analysis tools • Motion acquisition using computer vision • Motion generation & execution algorithms	• Automatic target recognition and reconnaissance • Demining and data acquisition • Navigation and planning • CAD/CAM and terrain modeling
ROTORCRAFT Georgia Institute of Technology Pennsylvania State University University of Maryland	• Efficient Low-Noise Rotors • Smart and Composite Structures • Low-Vibration Dynamic Systems • Highly Reliable, Safe Operations • Digital-Optical Integrated Fit Controls • Day/Night Adverse Weather Capability • Affordability: IPPD • Advanced Drive Trains	• First Principles Based Prediction of R/C Aeroacoustics • Investigation of Rotor Tip Vortex Formation & Decay Using 3-D LDV • Robust & Adaptive Flight Controls • Safe Transient Rotor Engage & Disengage • Computational Fluid Dynamics for Rotor Wakes • Basic IPPD Research for Affordable R/C Design • Modeling of Rotor Wakes in Maneuvering Flight

Table V-3. Army Multidisciplinary University Research Initiative (MURI) Centers

RESEARCH AREAS/ PARTICIPATING UNIVERSITIES	SCOPE	FUTURE PLANS
Terminating in FY1999		
MICRO GAS TURBINE GENERATORS Massachusetts Institute of Technology	• Develop high power, high energy density power sources • Develop high aspect ratio fabrication of SiC • Very small, high speed electrostatic generators • Very high speed bearing systems	• Very compact turbo compressors • Compact recuperator systems • Microcombustors for hydrocarbons
SMART COMPOSITE STRUCTURES Massachusetts Institute of Technology	• Develop advanced technologies for the control of electromechanical systems • Investigate solid state actuator and sensor technologies and structural control for critical rotorcraft applications	• Active Materials Technology • Active Composites Mechanics and Manufacture • Distributed Control Technology • Applications Testbed Program
MESOSCALE PATTERNING FOR SMART MATERIAL SYSTEMS Princeton University with Harvard University	• Mesoscale (1nm-1mm) patterning • Laser stereolithography • Self-assembled monolayers and templates	• Microcontact printing of ferroelectric ceramics • 3 dimensional co-assembly of composites • Mechanical characterization of patterned strictures
HIGH-PERFORMANCE FUEL CELLS University of Minnesota	• Improved anode electrocatalysts for direct oxidation of methanol • Improved membranes with low methanol permeability • Develop a model for small fuel cells	• Develop lower cost materials with sufficient lifetimes for military applications • Develop methodology to functionally tether homogenous catalysts to electrode structures • Develop catalysts for direct oxidation of alkanes
INNOVATIVE MESOSCALE ACTUATOR DEVICES FOR USE IN ROTORCRAFT SYSTEMS University of California-Los Angeles	• Integration of ferroelectric actuator and Si-based MEMS processing technologies • Model and understand ferroelectric actuator behavior • Investigate active control of dynamic stall and vibration reduction in rotorcrafts	• Determine mechanical/tribological properties of MEMS structures • Investigate high field, pulse mode operation of batteries • Simulation of unsteady aeroelastic behavior of rotorblades
MEMS-BASED SMART GAS TURBINE ENGINES Case Western University	• MEMS sensor/actuator arrays • SiC-based MEMS structures • Feedback control	• Pressure, heat flux and ice detection sensors • Flow control microvalves • CAD-based design • High temperature sensors/actuatros • Distributed control
THERMOPHOTOVOLTAIC ELECTRIC GENERATOR University of Western Washington	• Develop robust infrared emitters • Improve power density of photvoltaic cells • Develop filter technology required for improved efficiency	• Develop high flux tailored spectrum emitters • Improve long wavelength response of GaSb photocells • Improve burner technology for logistics
Terminating in FY2000		
FUNCTIONALLY TAILORED FIBERS AND FABRICS RESEARCH North Carolina State University with Akron University & Drexel University	• Functionally tailored textiles and fabrics • Advanced fibers and polymers • Multifunctional and smart materials • Textile and textile-based composite manufacturing	• Electrospinning if high performance fibers • Clothing for comfort and battlefield threat protection • Smart materials for camouflage, signature suppression and soldier recognition • Flexible and rigid armor composite materials design
ALGORITHMICS OF MOTION University of Pennsylvania	• Motion acquisition using computer vision • Motion generation with planning algorithms • Motion execution using control techniques	• Automatic target recognition • Reconnaissance and surveillance • Navigation and mission planning • Demining and data acquisition
APPLICABLE AND ROBUST GEOMETRICAL COMPUTING Brown University	• Geometric computing • Development of robust algorithms • I/O memory management	• Terrain modeling • CAD/CAM • Geometric libraries and visualization software
LOW POWER LOW NOISE ELECTRONICS University of Michigan with University of Colorado-Boulder University of California-Los Angeles with University of California-San Diego	• Communications RF components • Radar RF components	• Comprehensive low power design • Power amplifier circuit interfaced with modulation/signal processing algorithms • High functionality/low power devices • High functionality/efficient antennas
INTELLIGENT TURBINE ENGINES	• Active control of gas turbines • Sensors/actuatros • Control architecture	• Combustor/compressor control • MEMS sensors/actuatros • Dynamic engine models • Nonlinear controllers

(Continued)

Table V-3. Army Multidisciplinary University Research Initiative (MURI) Centers (Continued)

RESEARCH AREAS/ PARTICIPATING UNIVERSITIES	SCOPE	FUTURE PLANS
Terminating in FY2001		
ACTIVE CONTROL OF ROTORCRAFT University of Maryland	• Exterior (rotor) noise and vibration control • Interior noise control • Transmission noise and vibration control	• Mach-scaled rotor tests • Comprehensive acoustic and vibration analysis techniques • Innovative noise and vibration control concepts
DAMAGE TOLERANT LIGHTWEIGHT ARMOR MATERIALS University of California-San Diego	• Novel materials and structures design concepts • Processing, fabrication and testing of materials • Advanced analytical methods	• Layered, oriented and gradient materials systems • Dynamic viscoplasticity models for anisotropic materials • Solution of inverse problems
DAMAGE TOLERANT LIGHTWEIGHT ARMOR MATERIALS University of California-San Diego	• Novel experimental methods and testing • Mechanics and mathematical modeling of materials and structures • Characterization of materials	• High speed double image speckle holography • Implementation of models into codes • Digitization and analysis of microstructures
LOW ENERGY ELECTRONICS FOR MOBILE PLATFORMS University of Michigan	• Top-down design methodology • Optimization of all systems design levels • Software implementation	• Minimum energy information exchange • Integrated platform system design • Adaptive and minimum energy processing • High performance devices and components
PHOTONIC BAND ENGINEERING University of California-Los Angeles	• Improved microwave/millimeter wave devices • Efficient microlasers and smart pixels • Low observables and IFF	• Photonic crystals for electromagnetics • Demonstrate low threshold lasing • Nonlinear image processing
INTEGRATED APPROACH TO INTELLIGENT SYSTEMS University of California-Berkeley	• Design of hierarchical control architectures for multi-agent systems • Perceptual systems • Framework for representing and reasoning with uncertainty • Soft computing approaches to intelligence augmentation	• Intelligence augmentation for human centered systems • Fully autonomous systems • Battle management
DEMINING Duke University	• Mine, ordnance, and explosive detection, identification, and location • Sensor and information fusion • Neutralization	• Mine detection and location under realistic weather and environmental conditions • Enhancement of detection probability • Minimization of false alarm rate
RAPID, AFFORDABLE GENERATION OF TERRAIN AND DETAILED URBAN FEATURE DATA Purdue University	• Advanced photogrammetric and image understanding research	• Development of tools for the generation of detailed three-dimensional terrain and non-terrain feature data • Tools for construction and management of such databases
PREDICTIVE CAPABILITIES BASED ON PERFORMANCE METRICS FOR AUTOMATIC TARGET RECOGNITION FOR MILITARY APPLICATIONS Brown University	• Quantitative understanding of ATR capabilities and limitations • Metrics for structured clutter • Metrics for scene complexity	• Analytical frameworks for classifying images • Algorithm-independent bounds on ATR performance • Metrics to predict and measure the performance of ATR implementation
BIOMIMETICS AND BIOMIMETIC PROCESSING University of California, Santa Barbara	• New processing methods • Multifunctional materials • Structural materials • E-M-O materials	• Armor concepts • High energy storage • Aqueous processing • Microlaminates

to support unique and innovative programs, including, for example, educational enhancements, research grants, collaborative research programs, instrumentation enhancements, and technical assistance. The Army's portion of the program, awarded by ARO grants, totals over $30 million. All of the DoD Infrastructure Support Programs seek to enhance programs and capabilities at HBCU/MIs with the goal of increasing the number of underrepresented minority graduates in the fields of science, mathematics, and engineering. See Chapter VII, Section C.2, for additional information on support of HBCUs/MIs.

4. Single Investigator Programs

A major contributor to the Army science base is the single investigator working at universities and, to a lesser extent, in industry. These Army-sponsored researchers act as a window to the academic world to sense the limitless possibilities of scientific discoveries. Individual investigators provide the Army with the ability to broadly impact the total science base and to quickly respond to and exploit opportunities that might arise. The research areas are relevant to Army needs and subjected to scientific peer review. History has shown that the single investigator program has contributed significantly to the Army science base, with eight Nobel prizes being awarded for Army-sponsored research. The areas of research pursued by the single investigator are reflected in the Surveys of Scientific Research, described in Section E of this chapter.

5. Other Academic Leveraging

In addition to the preceding academic programs, the Army is significantly leveraging several other major academic institutions and consortia. For example, by becoming a member in the Rutgers University Center for Advanced Food Technology, the Army benefits from industry and academic sponsorship of research by a factor of almost 50 to 1. Access to pertinent research on food science and technology supports and complements Army efforts. The Army participates with industry and academia in the University of Massachusetts Center for Research in Polymers, where new polymers and polymeric materials are explored. The Army also participates, along with industry, in academic consortia that support textile research. One consortium is located in the Philadelphia area (Temple University, Drexel University, and the Philadelphia College of Textiles and Science). The Army benefits extensively from the ongoing research in these consortia.

D. Intramural Program

The intramural/in-house basic research program of the Army provides a direct flow of ideas and technologies into the Army's developmental activities, and is an essential means to attract and to nurture scientific expertise. Army scientists and engineers form a primary resource for the assessment of advances and breakthroughs in the scientific community at large, for determining the best way to exploit these advances and breakthroughs for military applications, and for developing long-range technology concepts. Army scientists and engineers are a primary interface between the Army's developmental activities and the civilian research community, and through their leadership, they stimulate civilian research into areas of military interest or with potential military payoff. Most recently, these scientists and engineers are also guiding Army research toward dual-use applications, where both the military and civilians will benefit. The Army's intramural/in-house basic research programs are administered by laboratories of the Army Materiel Command, Army Medical Research and Materiel Command, the Army Corps of Engineers, and the Army Research Institute. Activities of these laboratories follow.

1. Army Materiel Command Research Philosophy

The Army Materiel Command (AMC) vests primary responsibility for intramural basic and applied research programs in the Army Research Laboratory (ARL). This federated, multidisciplinary laboratory also provides analysis and technical consultation to all Army elements. To ensure the flow of innovative projects, ideas, and technical opportunities required for developmental activities in the Army's continuing force modernization program, ARL maintains a focused basic and exploratory research program closely coupled with the academic and industrial sectors of the research community and supported by a mix of institutional funding complemented by support from customer programs.

The Army Materiel Command has a key research initiative to support the Army's thrust to digitize the battlefield. The objective of the Army digitization effort is to ensure the superiority of our command and control system by providing warfighters with a horizontally and vertically integrated digital information network. This network will provide a simultaneous, consistent picture of the battlefield from soldier to commander at each echelon, as well as across all the services and allied forces. The Army Research Laboratory (ARL) has prime responsibility for the AMC's Intramural research program and this program has recently been enhanced by the development of a Federated Laboratory concept.

The Federated Laboratory construct for conducting research is an innovative approach to integrating external research relevant to battlefield information systems, where the private sector has a substantial technology capability, with internal ARL research through the establishment of consortia in critical technology areas. Rather than developing or maintaining in-house research capabilities across the entire technological spectrum, this approach leverages external expertise, facilities, and technologies in areas where the private sector has both the lead and the incentive to invest, such as in telecommunications technologies. The intent is to form distributed, public-private sector teams that together conduct research, develop new technologies, and employ existing, state-of-the-art concepts and infrastructure available in industry, academe, and the Army. This approach will produce an effective synergy between government, industry, and academe that will provide the maximum return on Army resources by:

- Adopting an integrated approach that combines the best of the public and private sectors to achieve future land warfare capabilities.
- Utilizing the Cooperative Research Agreement to provide flexibility that is not possible with conventional instruments such as contracts or grants.
- Conducting true collaborative research between the government and consortia that consist of a diverse and multidisciplinary team of researchers from academe, industry, and historically Black colleges and minority institutions (HBCU/MI).
- Fostering and formalizing collaboration through the exchange of researchers from government to consortia and from consortia to government. This staff rotation is a foundation of the federated laboratory process and the target goal is to have twenty percent of the researchers on long-term rotation at any given time.
- Employing a unique management concept where the government and the consortia, through a Consortium Management Committee, collaboratively develop and adjust research plans as formalized in the Consortium' s Articles of Collaboration.
- Integrating the ARL federated research program with those at other Army and DoD components to ensure that there will be a smooth transition of research results, and that there is no duplication of efforts.
- Fostering a technical management approach that ensures that the consortia programs are integral to the overall ARL program, and that creates an environment where academic, industry, and government researchers can identify and collectively address key Army technology gaps.
- Providing a way to adapt commercial technologies to the unique needs of the military environment, and allowing government research to impact the industry protocols and standards of the future.

In January 1996, the Army awarded three Federated Laboratory Cooperative Research Agreements in these research areas:

- Telecommunications/Information Distribution
- Advanced and Interactive Displays
- Advanced Sensors

The selection of research areas was based on the needs of the Army's Digitization Initiative and the priority of the research programs to meet critical technology gaps in the Force XXI vision. A listing of the consortia participants is given in Table V-4. A finalized research plan that describes the planned work for 1996 and 1997 is currently in place.

ARL maintains two major centers of gravity. The one at Aberdeen, MD, maintains a predominantly in-house program focused on armor, armament, and soldier systems. In these

Table V-4. Federated Laboratory Consortia Participants

	TELECOMMUNICATIONS/ INFORMATION DISTRIBUTION	ADVANCED AND INTERACTIVE DISPLAYS	ADVANCED SENSORS
Industry Lead	Lockhead Sanders	Rockwell International	Lockheed Sanders
HBCU/MI Partners	Howard University Morgan State University	North Carolina A&T	Clark Atlanta University University of New Mexico
Academic & Industry Partners	Bell Communications Research City College of NY GTE Laboratories MIT Motorola University of Delaware University of Maryland	Microelectronics Center of NC SYTRONICS Univ of Illinois	Environmental Research Institute of Michigan Georgia Tech Research Institute Lockheed Missiles & Space Co MIT Ohio State Univ Research Foundation Stanford Univ Texas Instruments Univ of Maryland Univ of Michigan

areas, there are unique Army requirements and historically strong in-house capabilities. At Adelphi, MD, ARL is developing a predominantly external program to "Win the Information War." Strengthened efforts in digital communications, battlefield command and control, and information science will build on the world-class capabilities of some of our nation's best institutions, rather than attempting to duplicate such capabilities in-house. Efforts with an in-house center of gravity will use about 60 to 80 percent of their resources in-house to support their recognized preeminence and uniqueness. Efforts with an external center of gravity will use 60 to 80 percent of their resources in affiliated "outside" organizations.

Research topics are selected based on their potential benefit to the Army as gathered through close liaison with users (TRADOC schools and Battle Labs) and commodity developers (RDECs, PMs, PEOs). Research approaches are selected based on awareness of the state of the art in the entire research community, ingenuity of investigator's approach, and resource availability. Projects are formulated to ensure focusing a critical mass of scientific personnel and facilities to the maximum extent possible through the federated laboratories various elements. This collaboration is furthered throughout the "open laboratory" concept, where scientists and engineers from nonaffiliated institutions are encouraged to come and work on topics of mutual interest at ARL's specialized facilities and ARL scientists and engineers are sent to reciprocating laboratories.

ARL's research efforts are coordinated by its Technical Directorates with the Army's RDECs through a formal technology planning process carried out with the cognizance of ARL's Board of Directors, consisting of the RDEC Directors, the Technical Directors of ISC's engineering center, and key individuals from AMC and DA Headquarters. Coordination with other Service laboratories is primarily through the Tri-Service Joint Directors of Laboratories (JDL) technical panels and Project Reliance. Cognizance of activities of non-affiliated academic institutions is primarily through participation in the COE programs and scientific oversight of extramural academic research supported by ARO. Cognizance of industrial activities is primarily through periodic independent research and development programmatic reviews, through Cooperative Research and Development Agreements (CRDAs), and through proprietary licensing agreements. Additionally, ARL scientists and engineers are encouraged to interact directly with their colleagues through papers and attendance at professional conferences and seminars, at the national and international level.

In addition to providing a direct flow of ideas and technology into the Army's developmental activities, ARL's basic research program is an essential means of attracting scientific talent and nurturing the continuing growth of our scientists and engineers. These programs form the primary Army resource for the assessment of advances between the Army's developmental and operational activities. Through their professional leadership they stimulate civilian research into areas of current military interest or future potential military payoff, providing the widest possible base for future advances. Specific programmatic activities are discussed in the Survey of Scientific Research summaries later in this chapter.

2. Army Medical Research and Materiel Command Research Philosophy

Relatively little of the Army's 6.1 funding in the medical area is invested directly in the development of new medical knowledge and technology. In light of the large investment of the civilian sector in basic biomedical sciences, the Army postures its medical basic research programs to exploit, rather than sustain, the medical technology base. Figure V-4 summarizes how military medical R&D programs differ from their civilian counterparts. To effectively leverage the national investment in basic biomedical research for military-unique needs, the Army's in-house and extramural medical basic research programs are intensively managed by the USAMRMC as integral components of one of the five functional areas of medical capability most critical to maintaining effective military medical technological superiority: (1) Infectious Diseases of Military Significance; (2) Combat Casualty Care; (3) Army Operational Medicine; (4) Medical Chemical Defense (see Section V.E.10); and (5) Medical Biological Defense.

The inherent complexity of the human organism requires that the biomedical knowledge base encompass a broad range of scientific and technological disciplines. It is critical that the Army maintain in-house biomedical expertise in all pertinent disciplines to maximize the benefits of "technology push," while investing in areas of specific interest to the military medical community, "requirements pull." The capabilities to effectively address military medical requirements, to design militarily useful and technologically superior medical solutions, and to rapidly transition basic R&D results into operational benefits are enhanced by the effective use of managers and decision makers who are both technically and militarily qualified. The availability of uniformed military medical scientists within the military medical R&D system has proven advantageous in ensuring that up-to-date scientific knowledge and technical capabilities are effectively translated into usable products—both for military health care providers and soldiers. Maintenance of effective dialogue with medical scientists in the civilian sector requires that the in-house staff maintain their

Figure V-4. Military versus Civilian Medical R&D

- **Military Works Different Problems**
  - CW/BW threat countermeasures
  - Diseases not generally found in the U.S.
  - Health hazards not common to the U.S. work place
  - Health care delivery in a combat field environment versus civilian hospital environment
  - Goals include minimization of lost duty time as well as health optimization
- **Military Problems Are Not Addressed by the NIH and Private Sector**
  - The NIH looks primarily at diseases affecting the U.S. civilian population
  - Civilian disease demographics and profit incentive focus private sector R&D, not military needs
  - The NSF works military problems on cost share basis
  - The Federal (non-DoD) medical sector is not structured for product development
- **Military R&D Must Be More Focused than Civilian**
  - No basic research without programmatic relevance
  - Science and technology more intensively managed to push transition
  - Exploits rather than sustains scientific capabilities
  - "Sense of urgency" uncommon in the non-DoD federal and civilian sector

Military Medical RDA Program Responds to Military-Unique Needs

involvement and expertise in basic medical science. Strong in-house programs of medical basic research have proven critical to maintaining the vitality of both the civil service and uniformed military investigative staff upon which future military medical advancements depend.

3. Army Corps of Engineers Research Philosophy

The Army Corps of Engineers conducts basic research at four locations which are geographically distinct and which have unique program objectives. The basic research philosophy of each of these four laboratories is summarized below.

The focus of basic research at the Cold Regions Research and Engineering Laboratory (CRREL) is to enlarge the knowledge base available for solving the special problems of seasonal and severe cold that occur in a great many parts of the world. The program is organized into studies of the properties and processes of snow, ice, and frozen ground (the three dominant materials associated with cold regions) and studies of the propagation and exchange of energy in these materials across the spectrum of wavelengths from seismic and acoustic to infrared, optical, and millimeter wave. CRREL vigorously pursues focused research objectives using a balance of theoretical, field, and laboratory investigations. Field efforts extend from the polar regions of the earth to the seasonally cold regions of the temperate climate zones. CRREL's physical resources are unique in the world and include low temperature laboratories, large low temperature geophysical and geotechnical experimental facilities, and research field sites in New England and Alaska. Complementary and supporting basic research is conducted through the Army Research Office, the Office of Naval Research, NASA, and the National Science Foundation.

The Topographic Engineering Center (TEC) conducts basic research programs in support of its mission in combat engineering to provide soldiers and their commanders with superior knowledge of the battlefield so that future Army force projection can be accurate, efficient, and, when required, lethal. In support of this mission, basic research is conducted in terrain analysis, image processing, photogrammetry, knowledge-based systems, data base development, battlespace environments, spectral photogrammetry and signal analysis, neural network applications, terrain visualization, data fusion, and image compression. This research is designed to advance and maintain a technology base that will provide superior technology in support of combat operations through development of terrain-related systems and information. Specific areas include work that will enhance visibility, improve selection of vantage points, aid route selection and navigation decisions, improve detection of features, and facilitate terrain visualization for real-time battlefield operation as well as modeling and simulation. The research includes the exploitation of full-spectrum remote sensing (including hyper-spectral) data; computer sciences, including artificial intelligence; and advanced photogrammetric and terrain visualization techniques.

The Construction Engineering Research Laboratories (CERLs) conduct basic research in support of their mission to design, maintain, and rehabilitate the Army's infrastructure and to sustain installation environmental quality. This research includes the advancement of the sciences required to develop the techniques, strategies, and tools to provide Army planners, designers, construction managers, and facilities operations managers with the basis for better decision making. Basic research also supports development of tools and technologies to enable Army environmental managers at all levels to meet environmental requirements, exercise stewardship of Army natural and cultural resources, and perform mission-essential functions without causing annoyance to the surrounding civilian population. The efforts include the development and advancement of technologies in the following areas:

- Concurrent engineering and smart materials research emphasizing the theoretical basis for reasoning about symbolic/graphical representations, development of object-oriented intelligent support tools for collaborative systems' and development of self-repairing and active damage control materials.
- Physical, thermal, chemical, and biological approaches to treatment of military-generated pollutants.
- Pollutant binding mechanisms to eliminate residual liability.

- Noise propagation, modeling, and management.
- Spatial data modeling to integrate and enhance environmental decision making.
- Characterization of cultural resources and ecosystems (biodiversity).
- Unique mitigation and management of resources to sustain lands for military use.

The Waterways Experiment Station (WES) executes a robust basic research program to develop the fundamental knowledge base required by the Army in the fields of civil and environmental engineering. Specifically, the research philosophy focuses on technology barriers for the Civil Engineering Reliance areas of Airfields and Pavements, Sustainment Engineering, Survivability and Protective Structures; and the Environmental Quality Reliance area of Installation Restoration. The civil engineering basic research program emphasizes the following:

- Determining and quantifying the nonlinear, hysteretic response of deformable soils to transient loadings resulting from high-speed curvilinear vehicle maneuver.
- Defining the constitutive behavior and penetration mechanics (including plastic deformation and fracture mechanics) associated with projectile impact on complex geologic and structural materials.
- Developing mathematical models needed for first principle analyses of explosive-induced ground shock and high-velocity projectile impact.
- Developing analytic models and advanced construction materials for the design and construction of permanent or expedient operating surfaces both within CONUS and within a theater of operations.
- Developing passive or responsive construction materials suitable for camouflage, concealment, and deception measures for fixed or long-dwell assets.

The focus of the environmental engineering basic research program is on the development of biological and chemical oxidative technologies for remediation of explosives- and organics-contaminated media found on the Army's installations, with emphasis on identification and elimination of undesirable intermediate products; the goal is to identify and quantify those factors that control the degradation of explosives, energetics, and organics in solids and ground water and develop environmentally acceptable remediation processes.

4. Army Research Institute Research Philosophy

U.S. Army Research Institute for the Behavioral and Social Sciences's (ARI) basic research program is conducted in support of ARI's applied research program, the Deputy Chief of Staff for Personnel, the Training and Doctrine Command, and other agencies. In addition to an intramural program, most of the research efforts are performed by university scholars under contracts or grants. These efforts arise from intensive outreach, interaction, and collaboration with the university scientific community, organizations such as the National Academy of Sciences, historically Black colleges and minority institutions, and individual researchers.

Two main characteristics distinguish ARI's program. First, because ARI's 6.1 program managers are collocated with ARI's applied research scientists, the program is formed, monitored, and transitioned through an interactive process. This interaction helps to make the results of the research more likely to be used. Second, because of the nature of its research domain, ARI's 6.1 program is performed both in the laboratory and in the field. Because the Army is used as a laboratory, the resulting research often produces products not only of conceptual and theoretical importance, but also of immediate practical importance to the Army.

Both major components of the basic research program are responsive to the Army's mid-term needs for new understanding and theory to support training systems research and manpower and personnel research. Lead assignments are established under Reliance and coordinated through the Scientific Planning Group on Cognitive and Neural Sciences. *Leader Skills for the 21st Century, Long Term Skill Retention and Transfer*, and *the Army in American Society* are the 6.1 scientific program areas in which ARI seeks fundamental, innovative research from the behavioral and social sciences community.

In training-related 6.1 research, efforts are continuing to better understand the conditions under which individuals learn tasks that are remembered for longer periods of time and to develop strategies to train skills more rapidly. Several factors have already been shown to promote long-term skill retention and more rapid learning. Research is also being conducted to better understand and measure individual spatial abilities. Results from this research directly benefit the more efficient design of curriculum, training courses, and simulators.

ARI's Reliance responsibilities in human resource development, leader development, and related manpower and personnel areas are reflected in its 6.1 research dealing with group and individual performance processes. As the only government agency with a specific research program on leadership, ARI has produced world-class research in this area with surprising findings on the role of leader experience. ARI research on decision making has been revolutionary, and has significantly affected the Army's conceptualization of battle command. Other research addresses issues that arise within the Army that are caused by major societal changes. To more effectively face emerging Army issues, ARI has now initiated research relevant to peace and stability operations.

5. In-House Laboratory Independent Research (ILIR)

Independent Laboratory In-House Research is an integral part of the Army's in-house basic research program. The purpose of ILIR is to allocate 6.1 discretionary funds to the directors of selected Army research organizations to fund in-house research projects of exceptional scientific quality which have high risk but also very high potential payoff to the Army's science and technology programs. ILIR funds are distributed to Army Research, Development and Engineering Centers (RDECs), the Corps of Engineers, medical laboratories, and the Army Research Institute.

ILIR is reviewed yearly using metrics developed to assess programmatic effectiveness. The yearly review examines the quality, relevance, productivity, and resources of the ILIR work performed by each organization and determines its ratio of ILIR funding for the following fiscal year. This review results in only the best performers being rewarded. Within each organization, innovative research proposals submitted by scientists and engineers compete for the ILIR funding through internal management and technical reviews of the proposals.

Successful ILIR projects, on completion, will typically define a start-up project for 6.1 or 6.2 mission funding within the organization. In addition to providing a pathway to the development of novel and high quality research projects, by providing support for the most innovative and often speculative ideas, this program is instrumental in enhancing the recruitment and retention of outstanding scientists and engineers. The creative atmosphere fostered in this manner is essential to the identification of emerging operational concepts and technology thrusts for the future.

E. Survey of Scientific Research

The Army has established a vigorous research program covering a wide range of disciplines to capture and exploit the new opportunities presented by research advances and discoveries. This program is executed primarily by university contractors and in-house laboratory and RDEC personnel and includes efforts in the physical sciences (mathematics, computer and information sciences, physics, chemistry, and electronics research); the engineering sciences (mechanics, civil engineering, energy conversion, aeronautics, and materials); the environmental sciences (atmospheric and terrestrial sciences); and the life sciences (biological, medical, behavioral, and social sciences).

Within this wide spectrum of research, several primary areas emerge that are of particular importance to tomorrow's Army:

1. Mathematical sciences
2. Computer and informational sciences
3. Physics
4. Chemistry
5. Materials science
6. Electronics research
7. Mechanical sciences
8. Atmospheric sciences
9. Terrestrial sciences

10. Medical research
11. Biological sciences
12. Behavioral, cognitive, and neural sciences

The following sections briefly describe each of these research areas.

1. Mathematical Sciences

a. Strategy

Mathematics plays an essential role in modeling, analysis, and control of complex phenomena and systems of critical interest to the Army. To achieve Army goals, research in several areas is important:

(1) Applied analysis

(2) Computational mathematics

(3) Probability and statistics

(4) Systems and control

(5) Discrete mathematics.

An investment strategy meeting with participants from ARO, ARL, RDECs, COE-WES, CAA, DUSA-OR, and academia identified several exciting research areas that will have significant impact on future Army technologies. Based on these recommendations, research priorities inside these areas are listed below.

b. Major Research Areas

Applied Analysis

Physical modeling and mathematical analysis for nonlinear ordinary and partial differential, difference, and integral equations for:

- Advanced materials, including smart materials and structure and advanced composites.
- Fluid flow, including flow around rotors, missiles, and parachutes, combustion, detonation and explosion, two-phase flow, and granular flow.
- Nonlinear dynamics for optics, dielectrics, electromechanics and other nonlinear systems; physics-based mathematical models of human dynamics.

Computational Mathematics

- Rigorous numerical methods for fluid dynamics, solid mechanics, material behavior, and simulation of large mechanical systems.
- Optimization: large-scale integer programming, mixed-integer programming, and nonlinear optimization.

Probability and Statistics

- Stochastic analysis and applied probability: stochastic differential equations and processes, interacting particle systems, probabilistic algorithms, stochastic control, large deviations, simulation methodology, image analysis.
- Statistics: analysis for very large data sets or very small amounts of data from nonstandard distributions, point processes, Bayesian methods, integration of statistical procedures with scientific and engineering information, Markov random models, cluster analysis.

Systems and Control

- Mathematical system theory and control theory: control in the presence of uncertainties, robust and adaptive control for multivariable and nonlinear systems, system identification and its relation to adaptive control, hybrid control, H-infinity control, nonholonomic control.
- Foundations of intelligent control systems: discrete event dynamical systems, hybrid systems, learning and adaptation, distributed communication and control, and intelligent control systems.

Discrete Mathematics

- Computational geometry, logic, network flows, graph theory, combinatorics.
- Symbolic methods: computational algebraic geometry for polynomial systems, discrete methods for combinatorial optimization, symbolic methods for differential equations, mixed symbolic-numerical methods, parallel symbolic sparse matrix methods, algorithmic methods in symbolic mathematics.

c. Other Research Areas

As noted above, mathematical modeling is increasingly being identified as critical for progress in many areas of Army interest. The mathematical and scientific tasks in these areas of interest are frequently of significant complexity. As a result, researchers from two or more areas of mathematics must often collaborate among themselves and with experts from other areas of science and engineering to achieve Army goals. Some examples of cross-cutting areas of research include the break-up of liquid droplets in high-speed air flow (for determination of the dispersion of chemical or biological agents spilled from intercepted theater-range missiles), computational methods for penetration mechanics, and automatic target recognition. For example, promising approaches to computer vision for automatic target recognition require research in a wide range of areas including constructive geometry, numerical methods, stochastic analysis, Bayesian statistics, probabilistic algorithms, and distributed parallel computing.

d. Benefits of Research

With the change from a predictable large threat to numerous and often unpredictable regional threats, the need for more flexibility in Army systems and more rapid development of these systems increases. As the cost of physical experimentation increases, the role of mathematical modeling becomes more important. Mathematical modeling is a major factor in assuring that a system is well designed and that it will work once built. In all of the following areas, mathematics is a fundamental tool required by the Army of the present and the future:

- Design of advanced materials and novel manufacturing processes
- Behavior of materials under high loads, failure mechanics
- Structures, including flexible and adaptable structures
- Fluid flow, including reactive flow
- Power and directed energy
- Microelectronics and photonics
- Sensors
- Automatic target recognition
- Soldier and aggregates of soldiers as systems: behavioral modeling, performance, mobility, heat-stress reduction, camouflage (visible, IR), chemical and ballistic protection.

Two of these areas bear further comment. Advances in analytical and computational fluid dynamics are required to understand detonation (see Figure V-5). Advances in modeling and computational capabilities are needed to support stochastic modeling and simulation of combat to assess changes in doctrine and tactics and to determine the cost effectiveness of new systems on the battlefield (see Figure V-6).

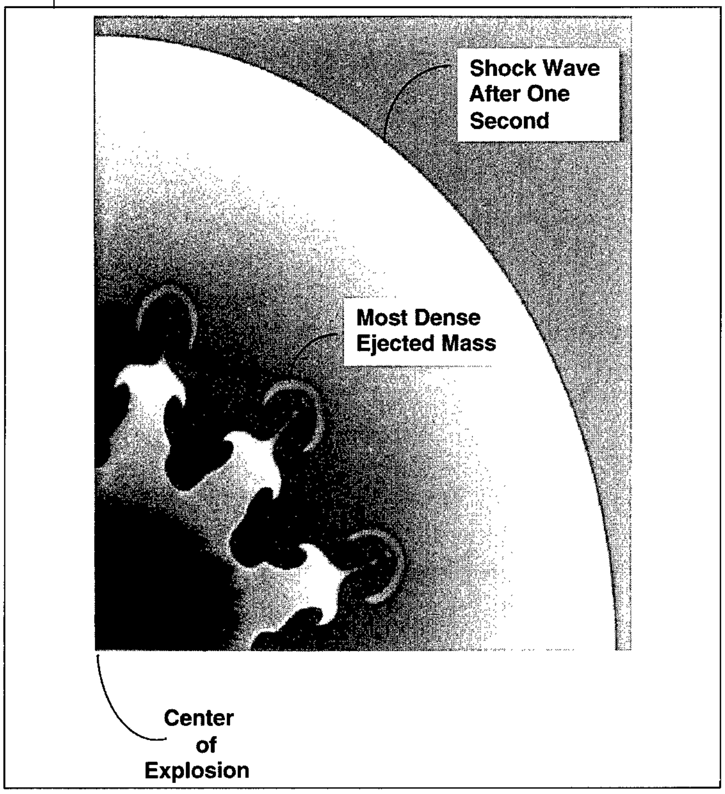
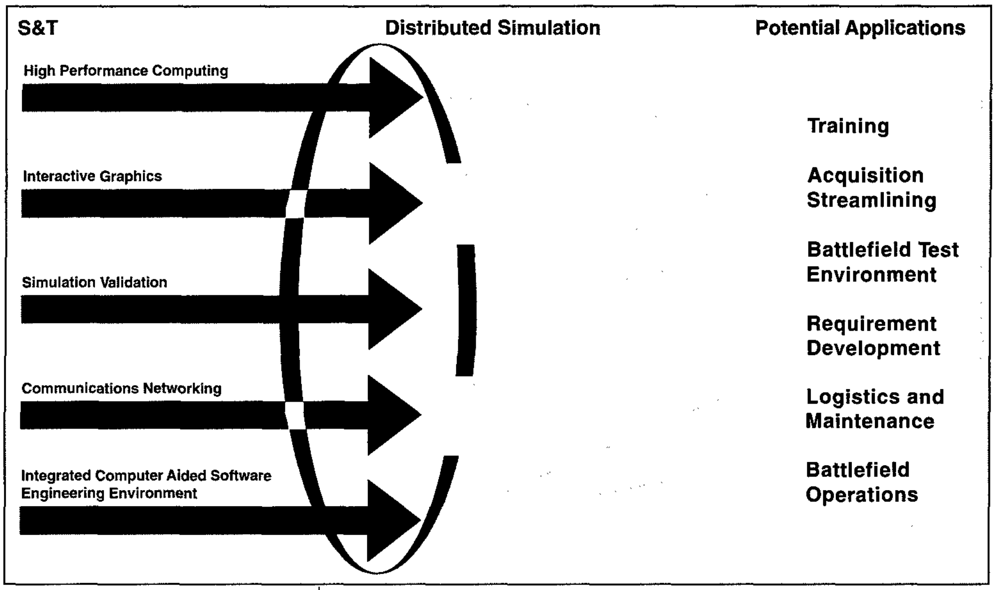


Figure V-5. Density gradient soon after detonation of an explosive in a gas. The quasi-spherical density contours produced by many previous computational techniques were nonphysical. More accurate highly convoluted contours are produced by new computational techniques developed under ARO sponsorship.

Figure V-6. Focusing Various Mathematical Inputs Toward Potential Military Applications Through Distributed Simulation



2. Computer and Information Sciences

a. Strategy

The computer and information sciences address fundamental issues in understanding, formalizing, acquiring, representing, manipulating, and using information. The advanced systems, including the software engineering environments and new computational architectures, facilitated by this research will often be interactive, adaptive, sometimes distributed and/or autonomous and frequently characterized as intelligent. Based on the recommendations from an investment strategy meeting among senior scientists from ARO, ARL, RDECs, TRADOC, DUSA-OR, CAA, COE, and academia, research in the following areas was determined to be important to the Army:

(1) Theoretical computer science

(2) Formal methods for software engineering

(3) Software prototyping, development, and evolution

(4) Knowledge base/database systems

(5) Natural language processing

(6) Intelligent systems

b. Major Research Areas

Theoretical Computer Science

- Formal models underlying computing technology, optimization of I/O communication, new computing architectures, multiprocessing, parallel systems and advanced architectures.
- Graph theoretic methods applied to parallel and distributed computation, models, and algorithms for the control of heterogeneous concurrent computing.

Formal Methods for Software Engineering

- Logics: formal logics for software engineering.
- Scalability: granularity and extensibility of formal methods.
- Software languages: specification languages, programming languages, interface languages.

Software Prototyping, Development, and Evolution

- Software engineering architectures: environments, tools, integrated tool sets.
- Graphical interfaces: multilevel displays for requirements elicitation, simulation, logic visualization.
- Software generation: invocation of formal methods, software reuse.
- Software evolution: change, merging, documentation.
- Software reliability: validation, verification.

Knowledge Base/Data Base Sciences

- Heterogeneous data structures: mediators, complex reasoning.
- Machine learning: methodologies for uncer-

tainty, incompleteness, information recognition and content-based retrieval.

- Multi-modal information: synthesis of knowledge from Multi-modal resources.
- Query/interrogation languages: domain-specific languages.

Natural Language Processing

- Text: content-based retrieval and understanding.
- Speech: translation, understanding, and generation with dialogue.

c. Other Research Areas

Computer-based systems that process information and transfer data and analysis among various Army commanders and units are essential for military success. The computer science and software issues that arise in this context often require input from a number of subdisciplines of computer science, as well as from other disciplines. Multi-sensor fusion, multi-image fusion, image understanding, language processing, distributed interactive simulation, multi-variable and multi-resolution methods for terrain modeling, scalable parallel algorithms and algorithms for processing large-scale data are but a few of these areas. In these areas, computer and information sciences research is organized in a cross-cutting fashion to provide the expertise needed to accomplish the Army goal (rather than remain within traditional disciplinary boundaries).

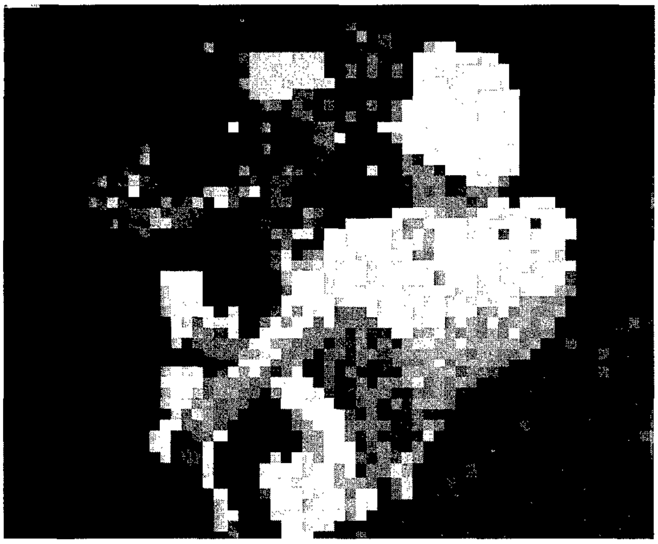
d. Benefits of Research

The contribution of the computer and information sciences to a well-equipped strategic force capable of decisive victory in conflicts in the Information Age is important in the following areas:

- Digitized battlefield
- Distributed command and control
- Information processing
- Distributed interactive simulation
- Design and validation of software and of large software systems
- Adaptive, anticipative systems
- Intelligent systems
- Human/machine interface
- Intelligence augmentation of human-centered systems
- Battlefield management

The Army is able to build interactive modeling and animation systems such as JACK (see Figure V-7) because of progress in these areas.

Figure V-7. JACK, an interactive computer-based modeling and animation system for studying human capabilities/limitations. JACK enables effective complex-system and interface design, and simulation for performance assessment/training.



3. Physics

a. Strategy

Based upon a strategy developed by the Physics Coordinating Group with representatives from participating RDECs, ARO, ARL Directorates, and the Topographic Engineering Center, a broad based research program in physics has been organized into five subject areas:

(1) Nanotechnology
(2) Photonics
(3) Obscured Visibility/Novel Sensing
(4) Optical Warfare
(5) Image Analysis Enhancement Technology

b. Major Reference Areas

Nanotechnology—The objective of nanotechnology is to develop the capability to manipulate atoms and molecules individually, to assemble small numbers of them into nanometer size devices, and to exploit the unique physical mechanisms that operate in these devices. This program emphasizes ultra fast phenomena, near-field microscopy, nanoscale manipulation, quantum processes for noise reduction and new radiation sources, and photonic band engineering, and quantum computing in concert with the National Security Agency.

Photonics—Photonics seeks to develop optical subsystems for military applications such as information storage, displays, optical switching, signal processing, and optical interconnections of microelectronic systems. Research opportunities exist in diffractive optics, hybrid signal processing, unconventional imaging, and sensors using optics.

Obscured Visibility/Novel Sensing—Obscured visibility/novel sensing seeks to provide the Army the ability to operate on the ground, over relatively short ranges in conditions of poor visibility. Control of physical signatures is now within our capability with the discovery of new materials and of enhanced backscatter.

Optical Warfare —The use of optical sensors and sources is analogous to the use of radio frequency detectors and sources. In the future we expect to see optical warfare become as important as electronic warfare. Nonlinear optical processes, tunable sources, and materials with special reflective, absorptive, and polarization properties and the ability to perform remote sensing of chemical and biological agents are research themes of current and future interest.

Image Analysis Enhancement Technology — The objectives of image analysis are to develop the fundamental limits and theoretical underpinnings of object recognition and image analysis. Specific areas of emphasis include image and algorithm metrics, image science and target acquisition theory, experimental verification, and model development.

c. Other Research Areas

Scientific metrics are needed to quantify image content and complexity and performance of image recognition and classification techniques. The metrics should relate the performance to measurable parameters based upon underlying principles. Image science and target acquisition theory draws upon computer and analytic models of targets and synthetic image generation technology. Contextual information from the scene as well as propagation effects are used. This activity will develop the theoretical underpinning of Automatic Target Recognition.

d. Benefits of Research

These programs support advanced technology development to provide increased signal processing, signal display, sensors protection and countermeasures, and target acquisition. Novel and improved radiation sources and detectors will continue to provide new capabilities for the Army as illustrated in Figure V-8 for uncooled thermal imaging, especially with the utilization of coherent systems and of multi-spectral imaging. In addition, atom optics are expected to provide new ultra-sensitive detectors and clocks with applications that include Global Positioning System and inertial navigation.

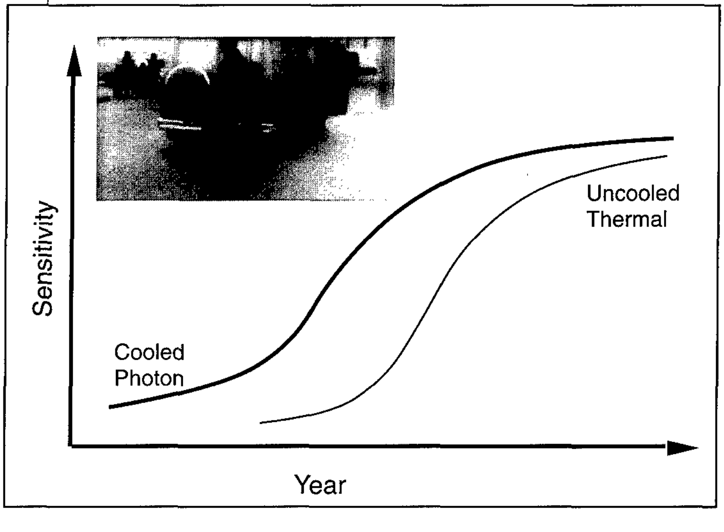


Figure V-8. Sensitivity Improvements of Uncooled Thermal Imaging Sensors. The photo insert is an infrared image from an uncooled thermal imaging array, taken at night. The uncooled arrays now have sensitivities approaching those of cooled photon detectors operating at video rates and resolutions. This competitive sensitivity is possible because of the long integration time allowed by the full two-dimensional array sensors. The uncooled arrays provide reduced size, weight, and power consumption, and they are much less expensive to produce because they are based on silicon IC manufacturing processes. They are extremely attractive for applications requiring a large number of units such as driver's night aids, thermal rifle night-sights, and individual soldier thermal vision aids.

4. Chemistry

a. Strategy

The Triennial Army Chemistry Long Range Strategy Planning Workshop was held in early 1995 with chemists from ARO, ARL, ARDEC, ERDEC, NRDEC, and WES. In early 1996 the Army Chemistry Coordinating Group met at Edgewood Research, Development and Engineering Center for its annual information exchange and planning meeting. Army chemists from ARO, ARL, ARDEC, ERDEC, NRDEC, CECOM, Army Demilitarization Activity, and U.S. Military Academy participated.

Following the Army Chemistry Long Range Strategy, research in chemistry continues to focus on programs for which the Army has lead responsibility:

(1) Chemical/biological defense

(2 Advanced materials research

(3) Explosives and propellants

(4) Soldier power

(5) Obsolete weapon demilitarization, installation restoration, and pollution prevention.

b. Major Research Areas

Chemical/Biological Defense

- Catalysts, reagents, and adsorbents to deactivate chemical threat agents.
- Micro-emulsions and other colloidal suspensions to dissolve and destroy chemical and biological threat agents.
- Reactive polymeric barrier materials for protective clothing.
- Detection and identification of chemical and biological threat agents.
- Chemical reactors for destruction of military toxic materials.

Advanced Materials Research

- Nonlinear optical materials for eye and sensor protection against laser threats.
- Smart materials that react to external stimuli.
- Cost-effective, rugged, light polymer composites and elastomers for vehicle, aircraft, and weapon components.
- Cost-effective, rugged, light polymers to protect against ballistic penetration.
- Fire retardants for vehicles.
- Surfaces resistant to wear and corrosion.

Explosives and Propellants

- Computer modeling of structure/function relations of energetic polymeric binders.
- Measurement of chemical chain reaction carrying species in propellant flames.
- Multiphase combustion models for solid propellants.

Soldier Power

- Catalysts for direct use of hydrocarbon fuels in fuel cells.
- Polymer electrolytes for fuel cells and batteries.
- Hydrogen storage for battlefield supplies for hydrogen/air fuel cells.
- New electrode materials for environmentally friendly batteries.

Demilitarization, Installation Restoration, and Pollution Prevention

- Oxidizers to clean up contaminated water.
- Combustion chemistry of chemical threat agents for improved incinerator design.
- Chemical reactors for destruction of toxic military materials.
- Analytical probes for locating below-ground contamination.

c. Other Research Areas

Polymer research develops new materials to protect the soldier from chemical and biological threat agents, ballistic penetration, and laser threats. New polymers and composites also provide tough, lightweight components for ground vehicles and aircraft. To meet these requirements, chemists synthesize new materials with tailored properties based on their knowledge of the relationships between polymer structure and function. Dendrimers—polymers branching densely from their origin—are an important new thrust area based on Army chemists' recognition of a technological opportunity. ARO and ARL are working together on an initiative to study a revolutionary new molecular architecture, e.g., dendritic molecules.

Chemical dynamics and kinetics research provides input for ignition and combustion models for explosive and propellant performance. Army scientists and engineers use these models to design more lethal, less vulnerable munitions and to diagnose malfunctions. Combustion research provides information on improved design of military waste incinerators and new reactors for demilitarization of obsolete weapons and installation restoration. Understanding of flame chemistry enables development of new, environmentally acceptable fire retardants for troop carriers and other Army vehicles. Basic research at ARL over the past decade on laser ignition of propellants has led to demonstrations using Army field artillery during the past year.

Research in electrochemistry develops efficient, lightweight systems to cool the soldier and provide electric power for communications, position location, and target designation. Significant advances in increasing energy density and useful life of power soldiers for the soldier continued during the past year under cooperative programs between ARO, CECOM, and DARPA.

Colloidal solutions can provide effective, noncorrosive reagents for decontamination of chemical threat agents. Catalysts and reagents enable clean-up of contaminated air streams. Chemical reactors provide new tools for effective, controlled transformation of Army toxic materials, especially obsolete weapons (chemical and explosive munitions), into relatively harmless substances. These efforts have important payoff for protection of the soldier against chemical threats and for clean-up of contaminated sites. The ARO Chemical Reactors program is now developing chemical process models for evaluation by Army program manager.

d. Benefits of Research

Figure V-9 shows a unique apparatus at United Technologies Research Center to measure surface temperatures on a burning strand of solid propellant. A laser beam enters from the right, Raman scattering occurs on the surface, and the spectrum is collected and subsequently dispersed in the monochrometer. Figure V-10 shows an apparatus being used at the Illinois Institute of Technology to measure properties

Figure V-9. United Technologies' Study of Burning Propellants

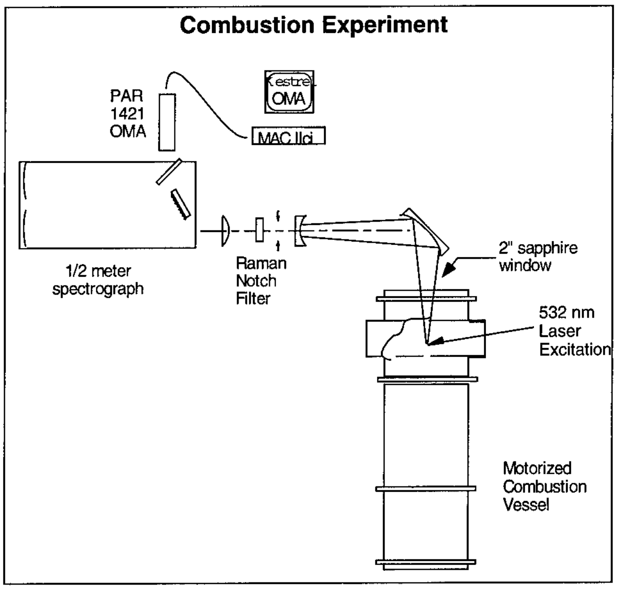
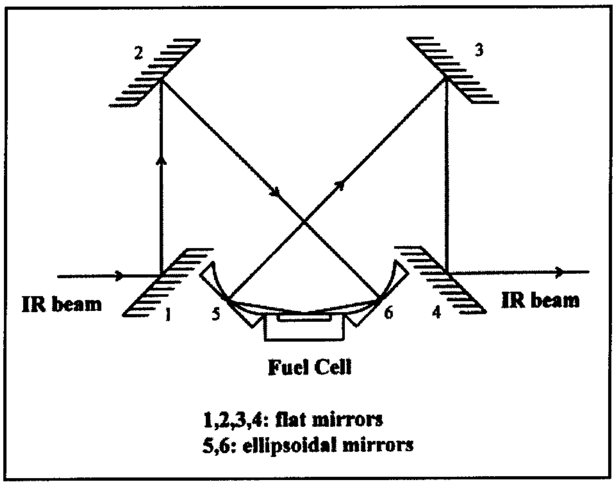


Figure V-10. Illinois Institute of Technology Study of Fuel Cell Catalysts



of fuel cell catalysts using infrared spectroscopy. As noted in Figure V-23 at the end of this chapter, chemistry supports numerous Technology Areas (Chapter IV), particularly Aerosace Propulsion and Power, CB Defense, Conventional Weapons, Environmental Quality, and Material Processes & Structures.

5. Materials Science

a. Strategy

Materials science research supports the entire Army materiel acquisition effort by ensuring that materials exist to fully satisfy future mission requirements for improved firepower, mobility, armaments, communications, personnel protection, and logistics support. Research priorities are defined in the Material Science Investment Strategy Plan, which is prepared by the Army Materials Coordinating Group. This Group is composed of scientists from ARO, participating RDECs, ARL Directorates, and TRADOC. This plan outlines a strong multidisciplinary program in materials science that emphasizes research in five broad areas:

(1) Manufacturing and processing of structural materials for Army vehicles and armaments

(2) Materials for armor and antiarmor

(3) Processing of functional (electronic, magnetic, and optical) materials

(4) Engineering of material surfaces

(5) Nondestructive characterization of components for in-service life assessment.

Related areas of materials research undertaken by other service and Government agencies will impact Army missions. To exploit advances in these areas, ARO actively leads the Tri-Service Materials Science Working Group under Project Reliance in planning and conducting basic research programs having a proper balance of service specificity and commonality. In certain areas of materials research, more than one service has a vested interest in supporting programs. These areas are leveraged to optimize the potential for creating scientific discoveries and breakthroughs. International leveraging is also emphasized by coordinating collaborative programs with ARO Far East Office and the European Research Office to provide a flow of new ideas and concepts in materials development.

b. Major Research Area

The materials field is highly interdisciplinary, encompassing such diverse specialities as physical metallurgy, solid-state physics, textile science, chemistry, biology and biotechnology, penetration mechanics, surface science, and materials analysis. Studies involving combinations of these disciplines are used to enhance our understanding of:

- Synthesis and processing of structural materials
- Deformation and fracture phenomena
- Defect engineering and processing
- Beam engineering and surface modification
- Plasticity and toughness of materials
- Nondestructive characterization

Synthesis and Processing of Structural Materials—Research in the structural materials arena is driven by Army needs for lighter and higher performance systems. These materials are often engineered to deliver superior performance to meet specific design requirements. The underlying challenges in manufacturing such materials are developing improved understanding of the interrelationships between processing, microstructure and properties, and developing innovative approaches to synthesize new materials reliably and at lower cost.

Deformation and Fracture Phenomena—This research focuses on developing an understanding of material behavior under static, cyclic, and dynamic loading conditions with emphasis on the response of advanced materials and composites to complex loading conditions that are imposed on high performance weapons systems.

Defect Engineering and Processing—Research in this area involves investigations underlying thermodynamics and kinetic principles that control the evolution of defects in materials, identifying the limits that defects impose on the synthesis and processing of future materials, and developing insight and methodologies for the utilization and manipulation of defects to produce materials with new or enhanced properties.

Beam Engineering and Surface Modification—Research in this area emphasizes surface engineering as this relates to materials modification, processing, and the reliability of Army systems in service. The goals are aimed at discovering atomic/molecular/macroscopic processes governing the deterioration and adhesion of materials.

Plasticity and Toughness of Materials—The goals of this effort focus on investigating novel approaches for processing materials with greatly improved properties with an emphasis on identifying the fundamental aspects of chemistry and structure that influence toughness and mechanical behavior under various time dependent stress and temperature conditions.

Nondestructive Characterization—Nondestructive characterization of materials and processes relate to investigating the concepts, techniques, and sensors for detecting and characterizing defects, contaminants, constituents, and microstructure that affect the performance and reliability of advanced materials, particularly where there is no existing nondestructive capability.

Overall, the approach to new materials development considers three levels of scaling. On the submicroscopic level, research is concerned with the manipulation of atoms and molecules and of the interactive forces which bind them. There is a strong emphasis on such topics as electronic and atomic structure, lattice vibrations, and the many interactions of radiation and particles with condensed matter. At the microscopic level, the field is concerned with the effects of chemistry, microstructure level, and phase transitions on the structural and functional properties of materials. At the macroscopic level, research is concerned with the continuum behavior of materials and composites. There are expanding opportunities for advancing the science of materials through continued integration and understanding of the interrelationships between the microscopic and macroscopic domains. This is reflected by the increasing integration of materials modeling and numerical simulation into materials science.

c. Other Research Areas

Much of the research is involved with laying the foundations for the development of future generations of materials and material processing technologies. These other research areas include:

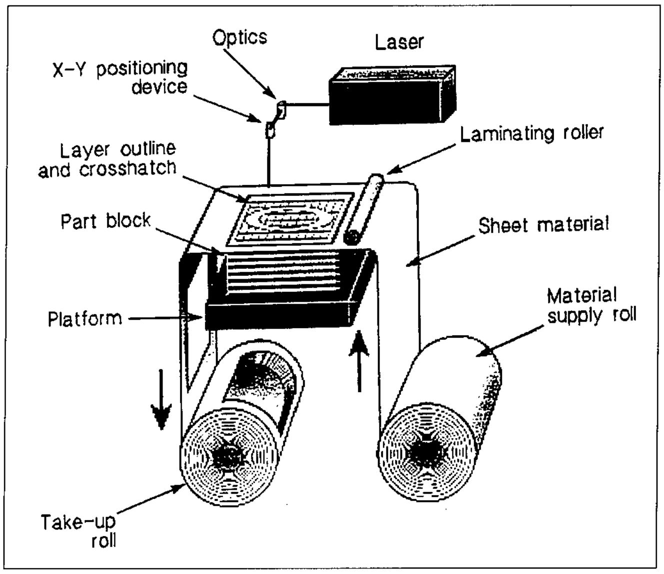
- Welding and joining
- Nanocomposites and biomimetic materials
- High toughness low density nonequilibrium materials
- Biosynthetic fibers
- Novel materials for thermoelectrics

A major interest for the Army is to introduce new approaches to small batch manufacturing, which can provide new levels of reliability at reduced costs. Flexible manufacturing approaches, like the composite lay up approach shown in Figure V-11, are under development. The goals of these programs are to streamline and automate the manufacturing processes that lead from the initial computer-aided design to final component production.

d. Benefits of Research

New generations of materials with vastly improved properties are also under development. Technology has now progressed to the point where it is possible to observe and engineer materials at the atomic scale. This opens the possibility of introducing much greater robustness into the design and performance of materials. For example, a new class of smart materials that is under development will be able to sense its environment and significantly alter its properties to adapt to changing conditions. Likewise, molecular recognition and self-assemble techniques, which mimic natural processes, are being investigated as a synthesis route to new classes of multifunctional supramolecular systems. This research is setting the stage for new generations of materials that will bear scant resemblance to the rudimentary materials technology that the Army depends on today. As noted in Figure V-23 at the end of this chapter, materials science supports practically all of the Technology Areas detailed in Chapter IV.

Figure V-11. The development of flexible manufacturing techniques promises to improve on the reliability and lower the cost of future Army materiel acquisitions.



6. Electronics Research

a. Strategy

Electronics is an enabling technology for all future Army systems for the digitized battlefield of Force XXI and the Army After Next. Electronics research provides the seminal knowledge to explore entirely new systems and the resulting enhanced warfighting capabilities and to create the fundamental technologies and critical components for the development of systems for the digitized battlefield. Army electronics research focuses on the generation of technology that will enable systems to function within the constraints imposed by the need for operation on small platforms such as the soldier, truck, armored vehicle, and helicopter used in highly mobile land warfare. This research provides the flow of ideas, concepts, and technology to the Army's developers to ensure the full integration of state-of-the-art electronics capabilities into advanced new systems in a timely and affordable manner. To achieve this goal and to maintain technological superiority, emphasis is placed on the investigation of a spectrum of near-term to far-term technologies. The research is reviewed, shared, transitioned, and transferred through the Reliance Electronics Scientific Planning Group (SPG) process, the Technology Area Plans, the Technology Area Review and Assessment (TARA), and the Electronics Coordinating Group (ECOG) activities.

b. Major Research Areas

An Electronics Research Strategy Planning Workshop was held with representatives from the RDECs, ARL, ARO, TRADOC, academia, and industry who identified and prioritized Army electronics research thrusts to satisfy projected requirements in the following areas:

(1) Solid-state devices and components with emphasis on ultrafast (terahertz switching speeds), ultradense electronics, and optoelectronic components

(2) Mobile wireless, tactical communications systems and networks to provide lightweight and reliable multimedia communications on the move

(3) Electromagnetics and microwave/millimeter-wave circuit integration for communications and radar systems that operate at the microwave through the terahertz spectral regions

(4) Image analysis for automatic target recognition (ATR) and information fusion focusing on the fundamental science of image analysis and sensor and data fusion

(5) Minimum energy, low power electronics and signal processing with focus on radio frequency devices and components to enable minimum detectable radiated energy and longer operational lifetime.

Solid-State Devices and Components—Research in this area can be categorized into near, mid, and longer term domains. Near-term research, which is pushing the current state of the art, concentrates on:

(1) Advanced semiconductor devices supporting Force XXI applications

(2) Quasi-optical techniques for advanced millimeter and submillimeter wave systems

(3) Components controlling very fast, high power electrical pulses

(4) Low-power electronics to conserve energy

(5) Advanced infrared sensor concepts

(6) Blue/green lasers

(7) Related materials issues

Mid-term research focuses on:

(1) High performance optoelectronic and optical processing components and architectures

(2) Microminiature sensors and actuators

(3) Research underlying a variety of field-controlled devices and structures that include the integration of microelectromechanical (MEM) structures with microelectronic, optoelectronic, electromagnetic, and acousto-electronic technologies

(4) Room temperature thermal imaging components

(5) Wide band-gap semiconductor technology

(6) Novel optoelectronic, microwave, and millimeter wave devices

To satisfy longer term needs, electronics research must provide for novel, robust, reliable multifunctional ultrafast/ultradense electronics and optoelectronic components and architectures. Conventional device structures cannot be scaled below certain size limitations. However, the opportunity exists for designing devices based upon new physical principles of operation leading to expanded functionality, to greater packing density, to higher speed, and to devices capable of operation at terahertz speeds.

Mobile, Wireless Tactical Communications Systems and Networks—Research in this area is driven by the need to communicate increasing quantities of information in near real time to commanders and soldiers on the digitized battlefield. Force XXI and Army After Next operational concepts call for a highly mobile force whose success is dependent on reliable voice, data, and video communications on the move information with minimum latency and varying quality of service requirements to ensure quick decisions and synchronous operations. Future battlefield communications systems will have to support a wide variety of data formats and traffic, modulations and coding, and network standards and protocols. There also will be varying requirements on signal bandwidth, data throughput, security, and delay that existing battlefield networks do not provide.

Electromagnetics and Microwave/Millimeter-Wave Circuit Integration—Research in this area focuses primarily on the issues in circuit integration, antennas, and propagation that will enable Army exploitation of the terahertz, millimeter wave, and high frequency microwave portion of the spectrum for communications, radar, and seeker systems for the digitized battlefield. Power combining techniques such as quasi-optics are critical in enabling moderate or high power millimeter wave systems with the advantages of solid-state electronics. Optical control of microwave and millimeter circuits provides the opportunity for low weight, low cost control of antenna arrays. Novel concepts for high efficiency, low loss antennas and antenna arrays are of importance, including active antennas.

Image Analysis and Information Fusion—A significant source of information on the digital battlefield is images generated by sensors that may be infrared, visible, or radar. The development of algorithms to enhance quality and extract information from images has been largely heuristic. There is insufficient fundamental understanding or unifying theory of image science with which to derive metrics of performance and to design image analysis algorithms. This research addresses these issues by pursuing research in the modeling of the interaction of targets and background clutter to enable their separation and to identify their causal relationship in the development of a basic theory of algorithms for object recognition. Methods are sought to validate the accuracy of simulated data and models so that they may be used with confidence to investigate and design image analysis for ATR.

Minimum Energy, Low Power Electronics, and Signal Processing—Research in this area addresses the need for low prime power consumption electronic and optical systems required for the 21st century land warrior in the digital battlefield of Force XXI. Current technologies for these systems require levels of power which result in low battery lifetime and high battery payloads to accomplish missions ultimately limiting the scope of missions. All weather vision requires opto-electronic imaging, nonlinear optics, high frequency monolithic microwave integrated circuits (monolithic microwave integrated circuits (MIMICs), submillimeter wave systems, photonics, and uncooled detectors.

The 21st century land warrior communications system will provide continuous communication on the move between commanders and soldiers on the battlefield. The systems will require ultra-high speed capability for handling complex voice, data, and video multimedia signal formats.

Since portable and lightweight prime power sources for the near future will be limited in capability, it is necessary to develop a new generation of design rules for electronics that operate with minimum energy requirements and dissipate very low dc power. This research will address highly efficient and low dc power consumption digital and radio frequency (RF) circuits and solid-state devices.

c. Other Research Areas

Solid-State Devices and Components—High resolution, high sensitivity, multicolor infrared imaging arrays are required for target acquisition, recognition, and identification. Research thrusts include advanced materials, novel device structures, and appropriate system architectures. Ultrafast signal processing computing will require advances in light emitters, such as microstructure laser diodes, operating at infrared and visible wavelengths. New system architectures are needed for increased data storage and efficient optical processing of images and video.

Mobile, Wireless Tactical Communications Systems and Networks—Research is conducted in network management, network protocols and architectures, message routing including flow and congestion control, forwarding algorithms, advanced switching technology, and the interfacing and integration of heterogeneous network types existing throughout the world. Methods for the design of large, distributed, mobile spread-spectrum packet radio network architectures, protocols, routing, and control are investigated. The use of adaptive array antennas in networks to provide spatial reuse of limited spectrum, to increase network throughput capability, to increase interference and jamming resistance, and to lower transmit power requirements is investigated.

Electromagnetics and Microwave/Millimeter Circuit Integration—Antennas for a wide range of frequencies with special properties such as wide bandwidth, multiband operation, and conformance to weapons platform physical profiles impact the operational capabilities of Army electronics systems, especially mobile and airborne systems. The complex interaction of multiple propagation paths due to diffraction, reflection, shadowing, and wave guiding have frequency- and position-dependent effects on ground-based and satellite systems.

Minimum Energy, Low Power Electronics, and Signal Processing—This research will develop a new generation of high-efficiency, low loss RF components such as amplifiers, mixers, and detectors. Solid-state devices will be developed to operate at low voltages, low currents, and high resistance to minimize device dissipation. Concepts will also be investigated to find modulation, coding, architectures, and algorithms that will minimize power consumption from the system-level point of view.

Electromagnetics and millimeter-wave integrated circuits research focuses on advanced antenna technology including conformal antennas and ultra-wide bandwidth antennas. Conformal antennas have Army applications ranging from antennas for the soldier through low profile vehicle antennas. Wide-bandwidth antennas are a key element for the successful introduction of the next generation of Army communications systems employing spread spectrum signals and instantaneous multiband operation.

d. Benefits of Research

Solid-State Devices and Components—As shown in Figure V-12, a key element in solid-state and optical electronics research is atomic level feature control to provide devices that will meet the Army's future technology needs in device integration and information capacity. Focused Army research in solid-state devices and components will result in significantly enhanced performance and functionality of electronic circuits, including:

(1) Faster, more portable, and more reliable systems for target identification

(2) Intelligent systems for better command and control of fire support missions

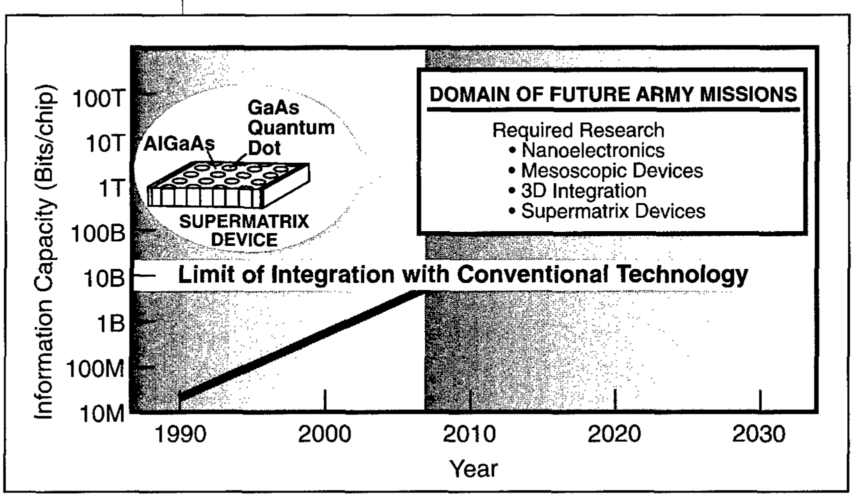


Figure V-12. Electronics Research. Research on novel electronic devices grown with atomic-level feature control is essential to achieving the level of device integration and information capacity required for the Army missions of the twenty-first century. Supermatrix devices such as the one depicted on the inset may have nanoscale features as small as a billionth of a meter. Mesoscopic devices operate on the basis of electron wave interference and as such portend fundamentally new types of electronic devices with greatly expanded functionality.

(3) Miniaturized computers and displays with improved processing capability

(4) Data fusion of multi-domain, compact, smart sensor suites

(5) Enhanced timing and location systems for autonomous weapons

(6) Optimized man-machine interface

(7) Ultrafast information processing in extremely small, massively parallel processors

(8) High data rate photonic communications

(9) Ultra-small integrated multi-functional sensors for the soldier.

Mobile, Wireless Tactical Communications Systems and Networks—Real-time signal processing is critical to communications, adaptive array antennas, and signal intercept as well as image analysis, target acquisition, and information fusion. Figure V-13 illustrates that as the complexity of the processing task increases, for example, from speech recognition to data fusion, the required signal and information processing throughput increases and the technology required to achieve that throughput also needs to advance. Signal and information processing are used in the implementation of image, radar, speech, antenna, and communication processing systems for applications in target detection, identification, and tracking; guidance and control; fire control; and communication. Research in fast, high-resolution null-and beam-steering and compact adaptive antennas to provide low-signature communications and improved signal intercept capability also is performed. Signal density on the modern battlefield is high and communication channels are nonlinear and dispersive, making the signal intercept problem especially difficult. This research includes advanced techniques for antenna array processing for accurate determination of the direction of arrival of signals and processing of signal parameters to develop new methods of detection and interception.

7. Mechanical Sciences

a. Strategy

The Army's reliance on mobile systems to perform its mission requires a major research effort in the mechanical sciences to provide the technology base that will enable the development of vehicles and their armaments with significantly advanced capabilities to meet the requirements of the future battlefield. The Army Mechanics Coordinating Group (MECOG), with representatives from all participating RDECs, ARL Directorates, and the Corps of Engineers' Waterways Experiment Station, developed a strategy for focusing the Army's future research programs in the mechanical sciences on the most opportune and important areas.

b. Major Research Areas

The MECOG developed the appropriate research thrusts and assigned priorities, while continually coordinating in-house and extramural research efforts in the four major fields of mechanical sciences that are critical to Army interests:

(1) Structures and dynamics

(2) Solid mechanics

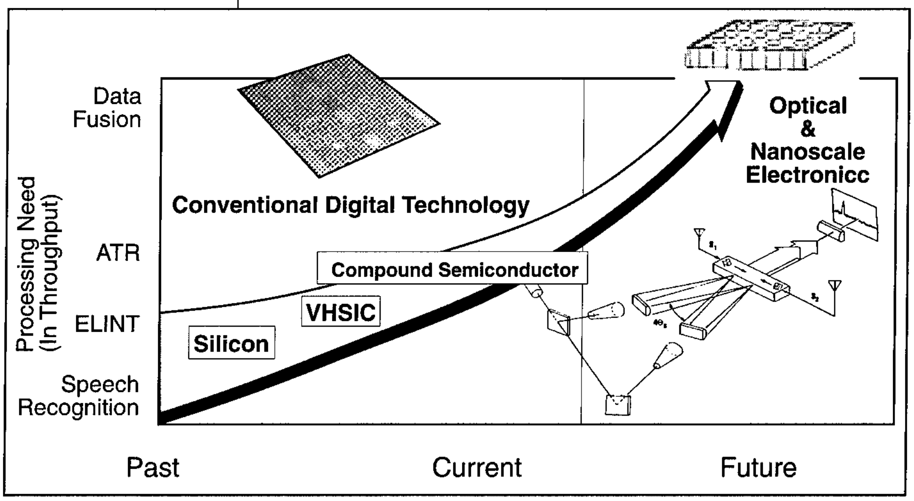


Figure V-13. Signal Processing Need. Speech recognition, electronic intelligence (ELINT), automatic target recognition (ATR), and data fusion demand increasing throughput. Nanoscale electronics, parallel and distributed processing, and optical processing research hold the promise for the future.

(3) Fluid dynamics

(4) Combustion and propulsion.

Structures and Dynamics—In the area of structures and dynamics the research topic areas are structural dynamics and simulation and air vehicle dynamics. The higher priority research thrusts in structural dynamics and simulation are ground vehicle and multi-body dynamics, structural damping, and smart structures and active controls. For example, the innovative use of smart structures, combined with other approaches, offers a promising avenue to the desired goal of significant vibration reduction in Army vehicles, particularly helicopters, by the next decade, as shown in Figure V-14.

Such reductions offer the possibility of an order of magnitude increase in weapon platform stability, with resulting improvements in the reliability of onboard equipment, the lethality of weapon systems, and greatly reduced pilot fatigue, equipment maintenance, and repairs. Smart structure applications to Army aviation and ground vehicles show significant promise in interior and exterior noise control, adaptive structural control, and enhanced vehicle performance. For air vehicle dynamics, the higher priority research thrusts are integrated aeromechanics analysis, rotorcraft numerical analysis, helicopter blade loads and dynamics, and projectile aeroelasticity.

Solid Mechanics—In the area of solid mechanics, the research topic areas are the mechanical behavior of materials, the integrity and reliability of structures, and tribology. The classes of materials of interest are functional gradient materials and heterogeneous materials. In mechanical behavior, the higher priority research thrusts are material response in the state of non-equilibrium or transient state including penetration mechanics and damage initiation and propagation. In addition, the mechanical response under coupled effects of electric, magnetic, and thermal fields is of great interest. The research in the area of integrity and reliability of structures focuses on damage tolerance, damage control, and life prediction. In the area of tribology, dynamic friction, lubrication, and surface topology in low heat rejection environments are emphasized.

Fluid Dynamics—For fluid dynamics the research topic areas are unsteady aerodynamics, aeroacoustics, and vortex dominated flows. The higher priority research thrusts in unsteady aerodynamics are dynamic stall/unsteady separation, maneuvering missiles/projectiles, and rotating stall and surge in turbo machinery. In aeroacoustics it is helicopter blade noise generation, propagation, and control; and in vortex dominated flows they are rotorcraft wakes and interactional aerodynamics.

Combustion and Propulsion—For combustion and propulsion, the research topic areas are small gas turbine engine propulsion technology, reciprocating engine technology, solid gun propulsion, liquid gun propulsion, and novel gun propulsion. The higher priority research thrusts in small gas turbine engine propulsion are in critical combustion processes, enhanced optimization, and integration of miniature sensors and active controls. For reciprocating engine technology the higher priority research thrusts are in ultra-low heat rejection environments, enhanced air utilization, and cold start phenomena. For solid gun propulsion the major thrusts are in ignition and combustion dynamics and high performance solid propellant charge concepts. For liquid gun propulsion they are in atomization and

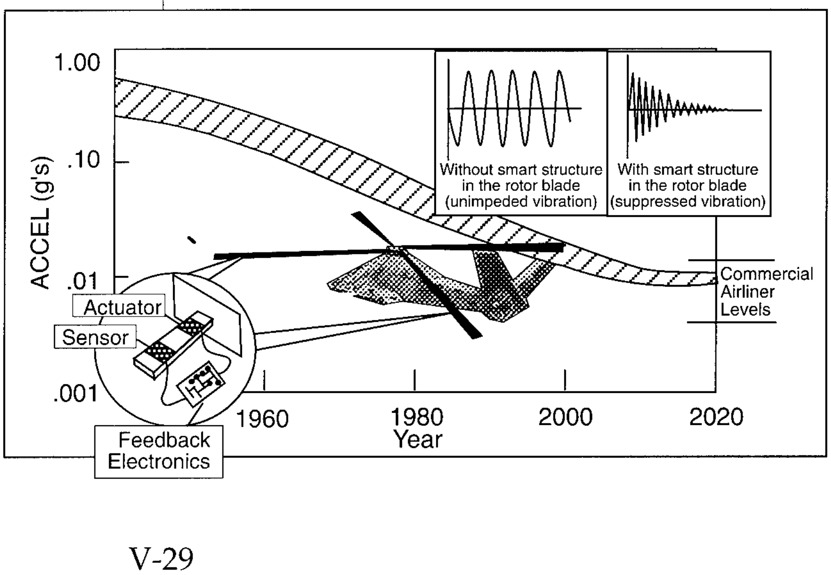


Figure V-14. As smart materials and structures are introduced into helicopters, vibrations and accompanying structural fatigue will be greatly reduced.

spray combustion, ignition, and combustion mechanisms and instability, hazards, and vulnerability. The higher priority thrusts in novel gun propulsion are electrothermal-chemical (ETC) propulsion, active control mechanisms, and novel ignition mechanisms.

c. Other Research Areas

In the research area addressing maneuvering projectiles, super computing has provided significant advances in predictive capabilities, and massively parallel super computing promises to couple computational fluid dynamics (CFD) with computational efforts in other disciplines. Current computational systems allow for the static CFD of complex shapes or propulsion systems. Future advances will lead toward multidisciplinary computations of maneuvering smart munitions, integrated propulsion systems, flight dynamics, guidance and control, structural dynamics, and divert technology. Algorithms are being researched to allow a smart munition to be flown through the computer, allowing the design evaluation of complex trajectory maneuvers. Concurrent with these efforts, complementary research is being pursued in CFD of multi-body aerodynamics to predict and define submunition dispense systems (see Figure V-15). Future multidisciplinary computations in this research area will lead to coupled dynamics and aerodynamics in hyper-velocity launch technology and low speed military delivery systems.

d. Benefits of Research

The development of high performance small gas turbines will continue to be advanced by anticipated progress in the prediction of rotating stall and surge in turbo machinery as well as the understanding of impeller/diffuser coupling and interactions through advances in 3-D computational fluid dynamic simulation of these flow fields. For example, 3-D computational fluid dynamic simulations of turbo machinery flows resulted in highly loaded, yet efficient turbo machinery components such as the advanced two-stage compressor configuration shown in Figure V-16. Future applications of this advancing capability to other gas turbine engine components will make possible the attainment of the ambitious Integrated High Performance Turbine Engine Technology (IHPTET) goal of an increase of 120 percent in the turbo shaft power-to-weight ratio by the year 2005, also shown in the figure. Mechanical sciences have a significant impact on five Technology Areas (Chapter IV): Aerospace Propulsion and Power, Air and Space Vehicles, Individual Survivability and Sustainability, Conventional Weapons, and Ground Vehicles.

8. Atmospheric Sciences

a. Strategy

The atmospheric environment impacts every aspect of Army operations. Fog, rain, snow, and aerosols and smokes from battlefield sources are a few obvious factors influencing Army strategy, mobility, and weapons delivery. Prior, quantitative knowledge of present and future environmental conditions, consequences, and limitations is essential for intelligence preparation of battlefield, for developing improved

Figure V-15. As computational capabilities (memory and speed) increase, more complex simulations of rotorcraft configurations become possible.

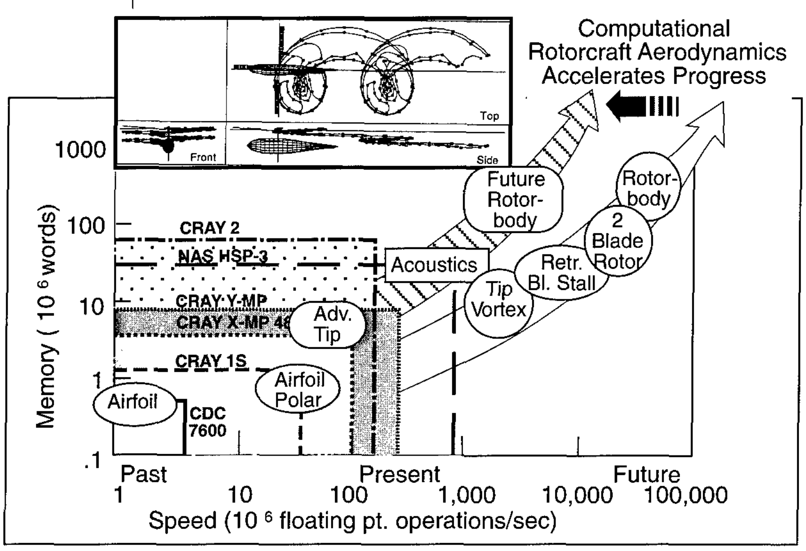
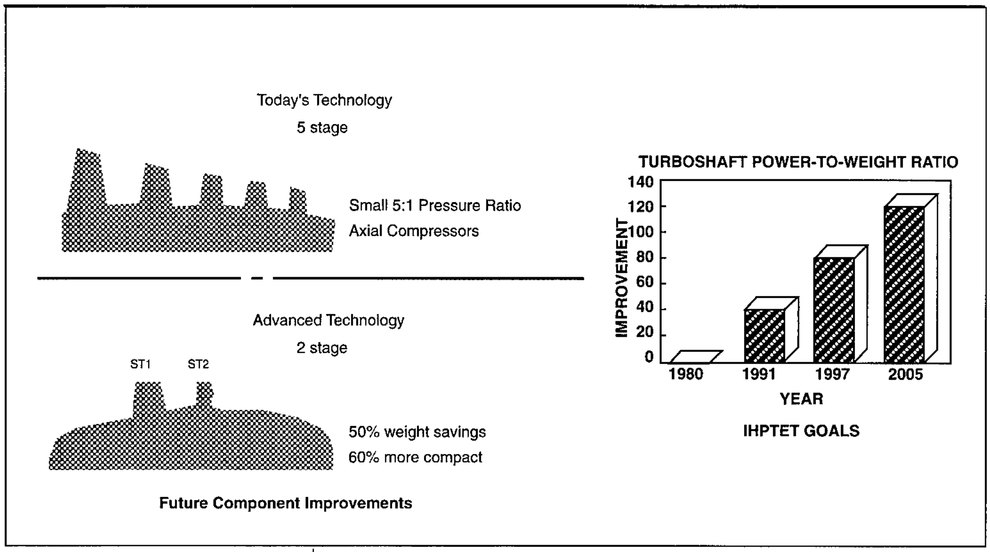


Figure V-16. Advances in 3-D computational fluid dynamics have produced a more compact, lighter weight, 2-stage compressor, resulting in improvements in turboshaft power-to-weight ratios.



weapon systems, and for enhancing the Army's "all-weather" capability. Under the Project Reliance, the Army has primary responsibility for scientific issues concerning the atmospheric boundary layer over the land. Furthermore, the Army has the responsibility for providing environmental data for its own needs at battlefield and smaller scales.

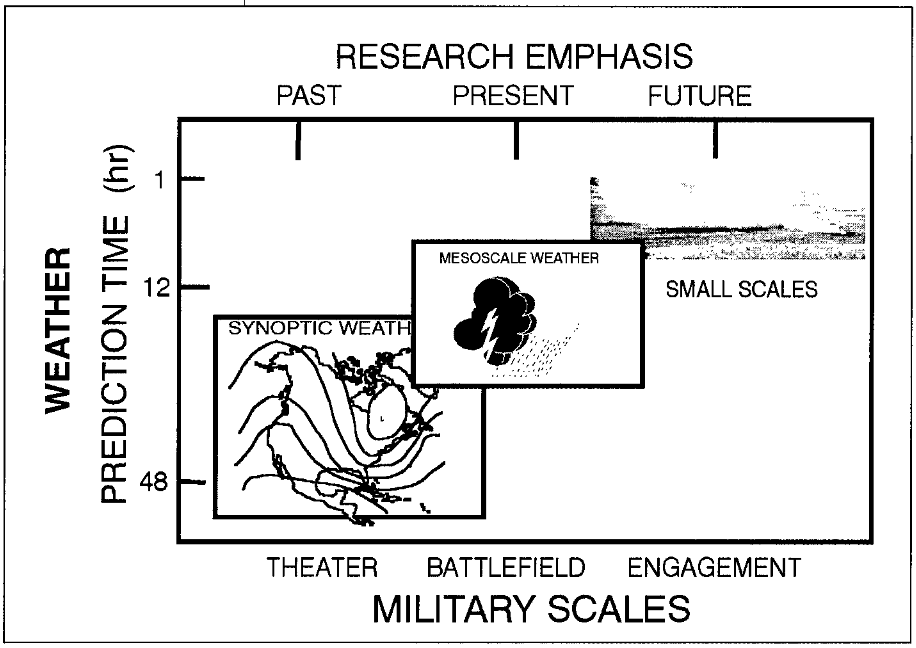
b. Major Research Areas

Better capabilities for predicting and using adverse weather effects as force multipliers require basic understanding of the physical processes of the atmosphere on scales ranging from continental to the engagement scales (Figure V-17). Basic research in the atmospheric science is multidisciplinary—using understanding of electromagnetic and acoustic propagation in the atmosphere, fluid dynamics and turbulence, radiative energy transfer, and thermodynamics of mixed phases of water are needed to assess the natural and induced environments over the land. The Army's Atmospheric Sciences Coordinating Group, with representatives from ARO, ARL Directorates, TECOM, NOAA, academia, and industry, developed a strategic plan for focusing future research by identifying and assigning priorities to promising research thrusts. Two primary subject areas were identified:

(1) Propagation and Remote Sensing

(2) Boundary Layer Meteorology

Figure V-17. In the future, weather prediction will improve and be applicable to smaller areas of military operations.



Present and future research focuses principally on the atmospheric boundary layer—where the Army operates—at high time and spatial resolution. These research thrusts stress fundamental understanding of the atmospheric boundary layer and the processes of its interaction with the natural ground surface. In particular, the scientific issues are of interest:

(1) Effects of heterogeneous conditions of surface heat, mass, and momentum exchange

(2) Stability conditions from very stable to fully convective

(3) Inhomogeneous turbulence on models of contaminant dispersion and of acoustic and electromagnetic propagation are emphasized

These issues have direct bearing on chemical/biological defense, atmospheric effects on weapon systems and operations, and predictability of atmospheric conditions.

To advance the understanding at these scales, high resolution measurements are needed but are currently unavailable. Development of a capability for remote sensing of the atmospheric boundary layer for high resolution of wind velocity, temperature, and moisture in four-dimensions (x,y,z,t) will continue as a major research thrust. The sensed data should provide quantitative information on the inhomogeneity of the atmosphere as a propagation (electromagnetic and acoustic) medium and as a dispersing medium for natural and induced aerosols. Propagation research concentrates on developing physically based models of atmospheric propagation in a variety of environments. The models address electromagnetic frequencies from the ultraviolet through millimeter wave and acoustic frequencies from 1 to 1000 Hz. Developing reliable imaging models for predicting atmospheric effects on sensors or system imaging performance, especially in inhomogeneous conditions, will improve evaluations of systems before going to field tests or deployment. The models will also be used to examine atmospheric effects on aided target recognition (ATR) performance and to improve ATR algorithm development. Fundamental studies investigate the interaction of electromagnetic waves with the natural earth surfaces for detection of subsurface objects. Passive spectroscopy of features of the earth surface is developing a major library of reflectance and radiance data to support the modeling and rapid detection of natural and manmade features, including camouflage.

c. Other Research Areas

Research efforts in understanding the detection, identification, and quantification of chemical and biological aerosols will continue. Research thrusts in this area are expected in the development of laboratory capabilities that are later transferred to field applications or techniques.

d. Benefits of Research

Boundary Layer Meteorology research serves all Services through improved characterization (parameterizations) of boundary layer processes over land in weather prediction models. It also supports multiple functions of the Army's Integrated Meteorological System in intelligence preparation of the battlefield. Research in turbulent dispersion of aerosols and gases leads to a significantly improved dispersion model applicable to open detonation/open burning of munitions; to improved prediction of transport and diffusion of chemical, biological, and nuclear materials on short time and space scales, over varied terrain shapes and ground covers, and all times of day; and to modeling effectiveness of smoke and other obscurants in realistic scenarios.

Remote sensing of wind fields will also enable detection of hazardous winds in aircraft landing zones, in paradrop zones, and in accidental release of hazardous gases or aerosols. Active and passive remote sensing research is essential to detection of objects in snow or on the ground, modeling and rapid detection of natural and manmade features, including camouflage, and millimeter-wave propagation at low grazing angles over and through a variety of vegetation.

9. Terrestrial Sciences

a. Strategy

Army doctrine has long dictated that commanders know the terrain. Coupled with weather, the resulting variety and dynamics of the terrain surface impact all aspects of the Army mission. Within the context of a force projection Army, terrain conditions are of paramount importance to mission planning, field mobility and logistics, systems performance, and unit effectiveness. The broad range of features and conditions found in cold region, mountain, temperate, desert, and tropical climates of the world can be either a formidable barrier or significant advantage for our forces. The key determinants are, first, a knowledge of terrain characteristics and processes and, second, the ability to incorporate that knowledge into our planning, operations, systems development, training, and doctrine. The topographic, geological, climatological, and hydrological character of the landscape are critical to mobility/countermobility, logistics, communications, survivability, and troop and weapons effectiveness. The digital battlefield requires detailed and sophisticated information about topography as well as terrain features and conditions. Environmental information and models need to be integrated with systems models to develop the ability to simulate and forecast system and unit performance. These capabilities are fundamental to the development of materiel that can perform effectively in worldwide environments, as well as doctrine that is appropriate for the wide range of conditions that might confront a force projection Army.

Terrestrial sciences research within the Army, which is directed toward meeting the above-stated objectives, is highly multidisciplinary in nature. The vision, long-term strategy, and research priorities for the terrestrial sciences are defined in the Environmental Sciences Strategy Plan, which is prepared by the Environmental Sciences Coordinating Group. This Group is composed of scientists from ARO, the Corps of Engineers laboratories (CERL, CRREL, TEC, and WES), academia, and industry. This plan outlines a strong multidisciplinary research program in the terrestrial sciences that emphasizes research in two broad areas:

(1) Solid Earth Sciences (topography and terrain; snow, ice, and frozen ground; and geotechnical engineering)

(2) Hydrodynamics and Surficial Processes (hydrometeorology; surface and subsurface hydrology; hydraulics; geomorphology; and coastal processes).

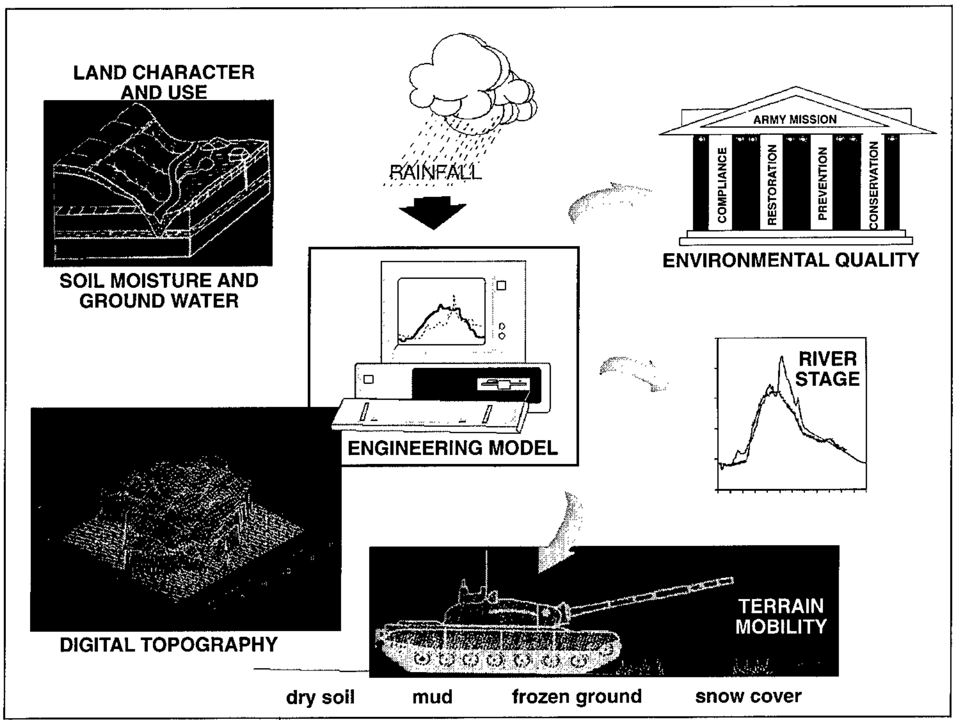
Major themes of the plan are reflected in the following paragraphs.

b. Major Defense Areas

Solid Earth Science—Characterization of the surface geometry and terrain features of remote or inaccessible areas is needed for enhanced planning and tactical decision making, as well as for tailoring equipment to the challenges of the natural environment. Fundamental data on the distribution and character of natural and man-made features, together with information about the dynamic condition of the terrain, are required for rapid mapping and such information must be coupled to models that quantify dominant physical processes to allow temporal forecasts of the conditions to be faced by soldiers and materiel. Enhanced remote sensing data acquisition capabilities (Figure V-18), system-organization and neural network theory, and advanced numerical methods are used to synthesize topography and terrain data base information. The Earth's surface features and materials interact dramatically with the boundary layer and weather systems, producing a highly sophisticated background within which targets are embedded. A knowledge of the many energy exchanges as a function of terrain character and climate, as well as their impact on the appearance of terrain scenes to sensing devices used for reconnaissance and target acquisition, is critical to both the development and deployment of these systems. Modeling of the physical processes operating on the Earth's surface is essential for the design of autonomous systems and the ability to realistically consider dynamic environmental effects in system performance and training simulations and in war games. No single factor has more influence on the performance or the ability to accomplish future missions with emerging autonomous or aided smart systems.

Hydrodynamics and Surficial Processes—Research in hydrodynamics and surficial processes addresses two thematic areas. The first relates to the hydrologic cycle and focuses on hydrometeorology, rainfall-runoff dynamics, and fluvial hydraulics as well as the relationship between surface and groundwater hydrology. The second relates to the geomorphological character of the surficial environment and focuses primarily on physical processes operating in arid/semi-arid, tropical, and coastal environments. A knowledge of the topography and physical character of landscape leads to the ability to estimate hydrologic/physical response and, therefore, an ability to

Figure V-18. **Terrestrial Sciences Thrusts.** Terrain mobility and other battlefield parameters are predicted through environmental modeling.



accomplish specific activities within the range of environmental conditions that might occur in different localities, seasons, and weather. Hydrometeorological conditions and surface hydrologic regime are determining factors in mobility/countermobility, thus impacting surface strength, creating barriers to movement, and/or at times allowing movement over normally inaccessible terrain.

c. Other Research Areas

Geotechnical research focuses on the strength and behavior of natural materials at a variety of scales, with a special emphasis on the cold/alpine regions. Of particular importance is understanding the time and temperature dependence of the physical, electrical, and chemical properties of snow, ice, and frozen ground, as well as the severe impacts of winter conditions on most equipment and soldier activities. Research in soil dynamics and structural mechanics is focused on the nonlinear response of deformable soils to transient loadings by vehicles, constitutive behavior of geological/structural materials to weapons effects, a determination of the response of granular materials to loading, and the failure mechanisms of pavement systems.

Environmental quality research is divided into four activities within the context of the Army mission of environmental stewardship:

(1) Cleanup

(2) Compliance

(3) Conservation

(4) Prevention

An aggressive cleanup research program investigates the fundamental physical, biological, and chemical processes governing the identification, evaluation, treatment, control and/or mitigation of past hazardous and toxic materials disposal practices. Research addressing soil, surface water, groundwater, and sediment contamination is conducted in four topical areas:

(1) Site characterization and monitoring

(2) Groundwater systems

(3) Site remediation (emphasizing explosives and heavy metals treatment)

(4) Environmental fate effects.

Compliance research seeks new technological approaches to permit Army activities while observing existing laws and regulations. Conservation research is directed at permitting the Army to preserve, protect, and enhance environmental, natural, and cultural resources consistent with the law and in concert with accomplishing the Army mission. Pollution prevention research focuses on minimizing or eliminating pollution at the source. Aspects of environmental quality research are also conducted within the basic research programs of the Biological Sciences, Chemistry, Material Sciences, and Mathematical Science.

d. Benefits of Research

Terrestrial sciences research is directly supporting Army Science and Technology Objectives (STOs) in Vehicle-Terrain Interaction, Digital Terrain Data Generation and Update Capability, Compliance Pillar, and Conservation Pillar. The complexity of the terrestrial environment can be a positive factor that the warfighter can leverage to operational/tactical advantage, when the features and physical processes occurring therein are understood at a fundamental level. Improved topographic and terrain information and an improved understanding of the physical nature and dynamic behavior of the surface environment—particularly as regards possible impacts on the simulating, planning, and execution of military operations—can be a dramatic force multiplier. Knowledge about the detailed character of a terrain and a capability to estimate when and where specific physical events or conditions will occur can be a great tactical advantage, in terms of both operational capability and preparedness. For example, an understanding of vehicle-terrain interactions is necessary for mobility modeling, an ability to remotely estimate precipitation and/or snowmelt infiltration and runoff is necessary to forecast hydrologic stage for river crossing operations, and an ability to predict sea-state conditions and near shore morphology is essential to successful logistics-over-the-shore operations. Research in support of the environmental stewardship mission will lead to the following results:

(1) The Army will conduct its activities in concordance with federal statutes.

(2) Contaminated sites on military installations will be cleaned up.

(3) Manufacturing pollution will be eliminated at the source.

(4) Natural and cultural resources on military installations will be well managed.

10. Medical Research

a. Strategy

In light of the large investment of the civilian sector in basic biomedical sciences, the Army postures its basic medical programs to exploit rather than sustain the medical technology base. To effectively leverage the national and international investment in civilian biomedical research into a meaningful contribution to military specific requirements, the Army's in-house and extramural basic medical research programs are intensively managed by the U.S. Army Medical Research and Materiel Command (USAMRMC) as integral components of the four medical functional research areas:

(1) Infectious Diseases of Military Significance

(2) Combat Casualty Care

(3) Army Operational Medicine

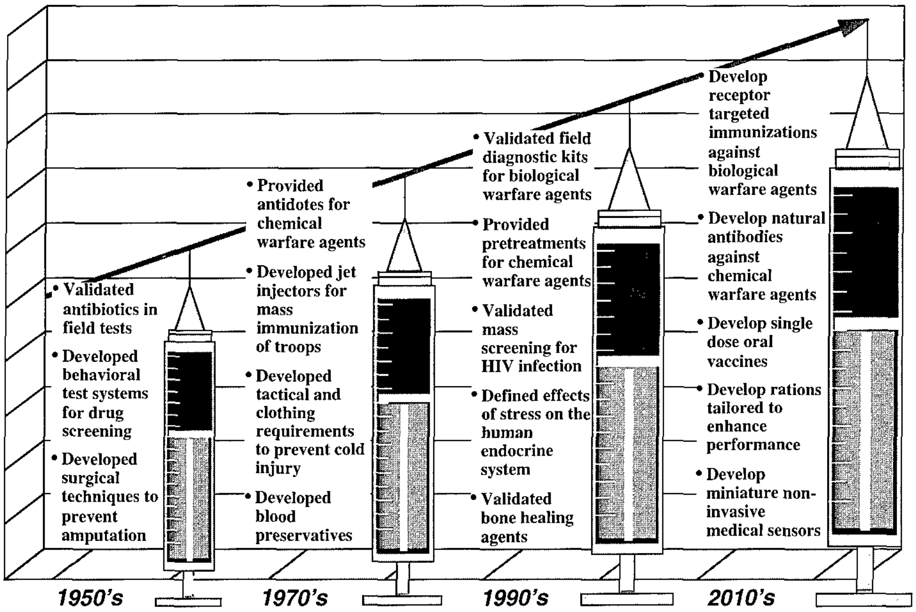
(4) Medical Chemical/Biological Defense

The Army basic medical research program is effectively integrated into the DoD biomedical research program through the Armed Services Biomedical Research and Evaluation Management (ASBREM) Committee. This coordination committee and the subordinate Joint Technology Coordinating Groups provide oversight and assurance that there is no unnecessary duplication of research efforts between the respective Services. This functionally aligned research investment ensures against technological surprises, which could overwhelm medical countermeasures to the health and performance of our Armed Forces. Both the leveraging of civilian investment and coordination within DoD allow the program to be focused on those specific technologies that will support the DoD mission to preserve soldiers' health and mission capabilities despite the extraordinary battle and non-battle threats to their health and well-being. Figure V-19 illustrates the impact that medical research can have on warfighting capability.

b. Major Research Areas

Infectious Diseases of Military Significance—Basic research in infectious diseases of military significance concentrates on prevention, diagnosis, and treatment of infectious diseases affecting readiness and deployment. Molecular biology will facilitate development of vaccines and prophylactic drugs to prevent illness, new vaccine delivery systems, and rapid diagnostic tests based on genetic probes. Special emphasis will be placed on alternative drug delivery systems or vaccines that can be administered infrequently, so that continual protection can be provided with minimal or no sustaining treat-

Figure V-19. Basic Research in Military Medicine. Basic research produces breakthroughs in medical technology.



ments. The Army is designated DoD Executive agent for this program and supports basic research efforts at Walter Reed Army Institute of Research (WRAIR), the U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID), and the Navy, in addition, to numerous research contracts at universities and other research institutions.

Combat Casualty Care—Basic research in combat casualty care is directed toward enhanced survivability (control of bleeding and field infusion devices), recovery from combat trauma, and the ability to provide intensive treatment during the evacuation process. Physiological research is performed to explore mechanisms of preventing secondary damage from acute injury and to determine approaches to managing casualty care during delayed evacuation. This includes work on biological interventions related to the induction of a hibernation like state. Basic research in combat casualty care is performed at WRAIR and the U.S. Army Institute of Surgical Research (USAISR).

Army Operational Medicine—Basic research within the Army operational medicine research area provides a basic understanding of the pathophysiology of environmental and occupational threats affecting soldier health and performance. In addition to the risks to health and performance from operations in extreme climatic environments, and the rigors imposed by military operations in and of themselves (e.g., sleep deprivation, jet lag, stress), operation of Army systems may present additional health hazards (e.g., electromagnetic radiation, noise, vibration, blast, and toxic chemical by-products). Most products in this functional area are informational in nature and serve as guidelines for materiel and combat developers (e.g., exposure standards for noise or vibration, work-rest cycles for heat). However, advances in neurosciences and molecular biology may lead to medical products which reduce susceptibility to fatigue or fatigue induced injuries. Biochemistry and neuroscience contribute to the nutritional studies designed to select natural food ingredients which will be converted by the body into physiologically and neurologically active metabolites. This will lead to a reduction in performance decrements due to combat stress and environmental extremes. Work in this area is conducted at the U.S. Army Research Institute of Environmental Medicine (USARIEM), the U.S. Army Aeromedical Research Laboratory (USAARL), and the WRAIR and through grants and contracts with universities and research centers.

Medical Chemical Defense—Basic research in medical chemical defense provides an understanding of the pathophysiology of threat chemical agents and seeks to elucidate chemical warfare agent mechanisms of toxicity so that rational countermeasure strategies can be directed against those agents. Reduction of incapacitating effects caused by chemical warfare agents and/or associated therapies remains a high priority research area. This program draws on the advances of neuroscience and molecular biology to develop more effective and less debilitating medical countermeasures. Although current research shows promise for the reduction of nerve agent toxicity, molecular biological approaches may ultimately produce safe and effective prophylaxis and treatments for the effects of blister and respiratory agents. The Army is the DoD Executive Agent for medical chemical and biological agent research and supports research at the U.S. Army Medical Research Institute of Chemical Defense (USAMRICD), USAMRIID, USARIEM, and WRAIR.

Medical Biological Defense—Medical biological defense focuses on military threat agents of biological origin. Basic research efforts work to identify infectious agents and toxins and to understand the disease processes or morbidity caused by them. Current research seeks to identify methods of stimulating host immunologic protection mechanisms, in order to provide protection against a broad spectrum of biological warfare agents rather than against specific agents.

Note that effective FY94, both the medical, chemical and biological defense programs were consolidated at OSD with the Army serving as Executive Agent.

c. Other Areas of Research

In addition to providing the basic understanding needed to improve recovery from central nervous system trauma, neuroregulators and neuromodulators may provide the key to controlling cellular and organ functions to improve wound healing, prevent organ failure, and provide better control of circulatory functions. Besides the strictly medical approaches in Army Operational Medicine, nutrition research will ensure that the soldier's diet will sustain health and performance across the spectrum of military operations. The Army is selected to serve as Executive Agent for all DoD nutrition research. Also, under investigation are protein carriers for transport of immunogenic peptides; vectored vaccines with multiple immunogenic properties; approaches to block the actions of threat agents on target receptor sites; and rapid evaluation of genetically altered microbes.

d. Benefits of Research

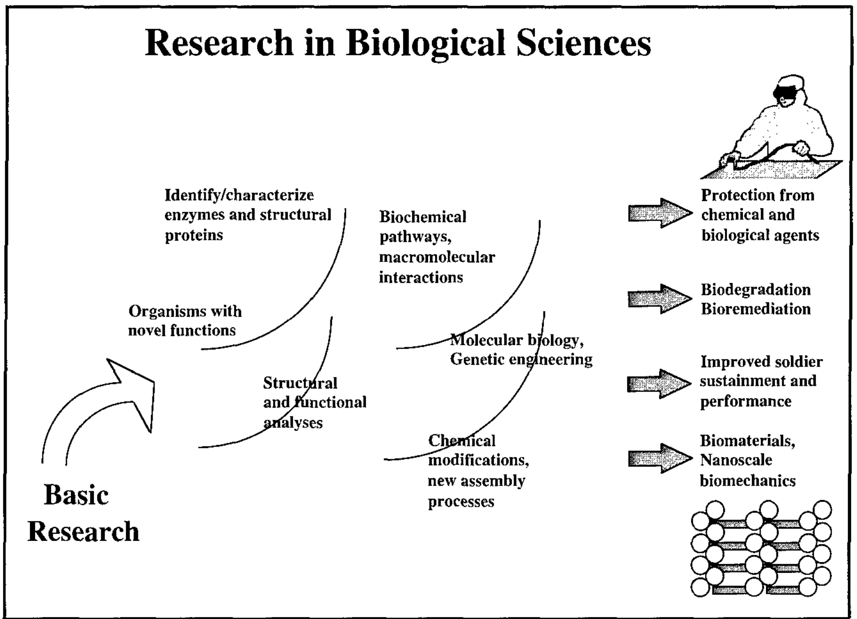
The Army's basic biomedical research programs provide the foundation for medical technological superiority in support of the National Military Strategy. In peace, medical technological superiority provides a critical element of deterrence, bolsters confidence among our allies, and provides a foundation for soldier readiness. In crisis, it ensures that threats to the health of the force are not a limiting factor in military options available to the National Command Authority. It contributes to the ability to provide humanitarian assistance, disaster relief, and national building. In war, it amplifies individual combat effectiveness, minimizes casualties, and reduces the death and disability rates among those who do become casualties.

11. Biological Sciences

a. Strategy

Basic research in the biosciences greatly increases our ability to understand and manipulate those aspects of the biological world that impact soldier sustainment and survival, and to identify biological materials and processes for future exploitation in materiel systems (see Figure V-20). In order to plan and execute high quality research relevant to Army needs in the biological sciences, an ARO Life Sciences Program Coordination and Planning Group including scientists from ARO, ARL, Army RDECs, MRMC, and the Corps of Engineers was established. Functioning as an advanced planning process team, this group developed a strategy for focusing research program activity in the biosciences to emphasize an appropriate balance between (1) capture of breakthrough scientific opportunities from the biological science research community and (2) alignment with Army and DoD science and technology objectives, and support of Army current demos and fielded items where applicable. While aimed at enabling novel capabilities, program efforts focus on providing the means to increase economic and environmental affordability in Army materiel production, on lessening the logistics burden, and on preventing the deleterious effects of chemical, biological, and physical agents from interfering with Army operations. Implementation of this strategy involves support of basic research in a number of sub-disciplines including, but not limited to, biochemistry, biophysics, molecular biology and genetics, cell biology, microbiology, physiology and pharmacology, encompassing studies at the molecular, cellular, and systems level.

Figure V-20. Basic research in the biological sciences is expected to have numerous military applications in the coming years.



b. Major Research Areas

Basic Research in Biotechnology—Basic research in biotechnology is directed toward fundamental studies which have as their goals the generation of new knowledge relevant to application of cell-derived tools to biological production processes. These studies seek to expand our understanding of interactions within and between complex biological macromolecules, including clarification of structure-function relationships wherever possible. They provide information on gene expression and its regulation, on enzyme mechanisms and on the general nature of biological catalysis, on receptor site characteristics and receptor-mediated metabolic pathways, and on compartmentalized and membrane-interfaced sub-cellular chemical processing.

Optimization of Physical Principles in Biological Systems—Optimization of physical principles in biological systems has as its main objective the discovery and description of novel theoretical principles and mechanisms, or materials with extraordinary properties, from biological sources, i.e., lessons from nature. The aim here is to identify and characterize, as completely as possible, those biological processes and structures that might be used directly in, or provide conceptual models for, development of engineered systems with potential for military application. For the lessons from nature paradigm to be effective, with successful emulation of the best of what nature has to offer, biologically derived unique architectures and systems function need to be fully described with regard to both process and product.

Physiology and Performance—Physiology and performance provides for basic research on biological responses and adaptation to environmental signals, and strategies that organisms use to survive adverse environmental conditions. Included here also are attempts to meet the need for fundamental new knowledge on sensory and motor capabilities and limitations, especially as they relate to peak soldier-machine system performance. Research efforts seek to clarify the functional physiology underlying the observation and interpretation of input cues by sensory systems. There is a need here to describe the influence of visual, auditory, and multiple source information processing, especially as impacted by stresses of various kinds. Studies of this sort may uncover strategies for limiting performance degradation during military operations, some of which place unprecedented physiological demands upon the soldier. Research issues concerning possible improvements in soldier sustainment are addressed here as well, including those dealing with innovative preservation and stabilization technology for rations.

c. Other Research Areas

Biodegradation—Biodegradation represents an area of basic research in microbiology and biochemistry aimed at the identification and characterization of cells and cell systems capable of breaking down materials relevant to Army activities, and the determination of conditions under which they are most active. It includes attempts at better understanding the molecular genetics; biochemical and physiological mechanisms underlying biodegradative processes in normal, extreme, and engineered environments; and the properties of materials that make them susceptible or resistant to biological attack. Research efforts here provide support for bioremediation of toxic wastes at military sites as well as information for protection of military materiel from biodeterioration.

Defense Against Chemical and Biological Agents—Defense against chemical and biological agents focuses on basic biosciences research impacting our ability to protect the solider from military threat agents. It encompasses fundamental studies on modes of action of potential agents on physiological targets, and characterization of those targets, including neurotransmitter interactions and other relevant cellular and systems involvement. A substantial portion of this work package relates to research addressing the properties of enzymes or enzyme-mimetics and the mechanisms of biocatalysis in threat agent detoxification. An additional area of primary concern in this work package is one geared toward providing a better understanding of how we might best detect the presence of one or more toxic agents on the battlefield. Approaches here include biologically based concepts for detection of either chemical or biological threat agents, as well as exploration of other means for rapid detection of biologicals.

d. Benefits of Research

A number of questions remain unanswered relative to the potential use of cellular genetic and biochemical manipulation in biotechnology for economically favorable and environmentally benign manufacturing processes, and for bioremediative strategies. Biosciences research, in providing answers to these and related questions, will enable metabolic engineering and bioprocessing to make significant contributions to Army and DoD missions and to the commercial sector for products and processes for off-the-shelf use by the military.

Research on bimolecular structural and functional materials, and their formation, guides us to the discovery of novel theoretical principles and of products and processes with extraordinary properties. These provide insight into the foundations of such phenomena as self-assembly, molecular recognition, catalysis, and energy transfer. Their study and understanding will lead to unique military, industrial, and consumer applications in such areas as sensors, smart materials, robotics, low observable technology, and biomimetic processing for composites. Likewise, the biological world offers many examples of exquisitely integrated signal transduction and multimodal information processing. Fundamental knowledge pertaining to how biological systems accomplish this will continue to have substantial impact on design of engineered information systems.

Attempts to better understand the genetic and biochemical mechanisms in diverse strategies of adaptation that organisms use to survive harsh environments or adverse conditions will lead to the development of new coping strategies for the soldier for overcoming physiological stress caused by extreme heat and cold, lack of sleep, poor nutrition, and injury. Studies in several subdisciplines of food science provide a basis for formulating, processing, and extending useful storage life of rations. They provide fundamental insight to better understand nutrient conversion for cellular energy and neurotransmitter function, and to enable control of microbial growth and stabilization of structural integrity during food processing, contributing not only to improved soldier satisfaction and enhanced long-term acceptability of combat rations, but also to improved soldier performance and endurance.

In general, these and other studies show great promise in terms of building a foundation for a number of emerging technologies (see Figure V-21).

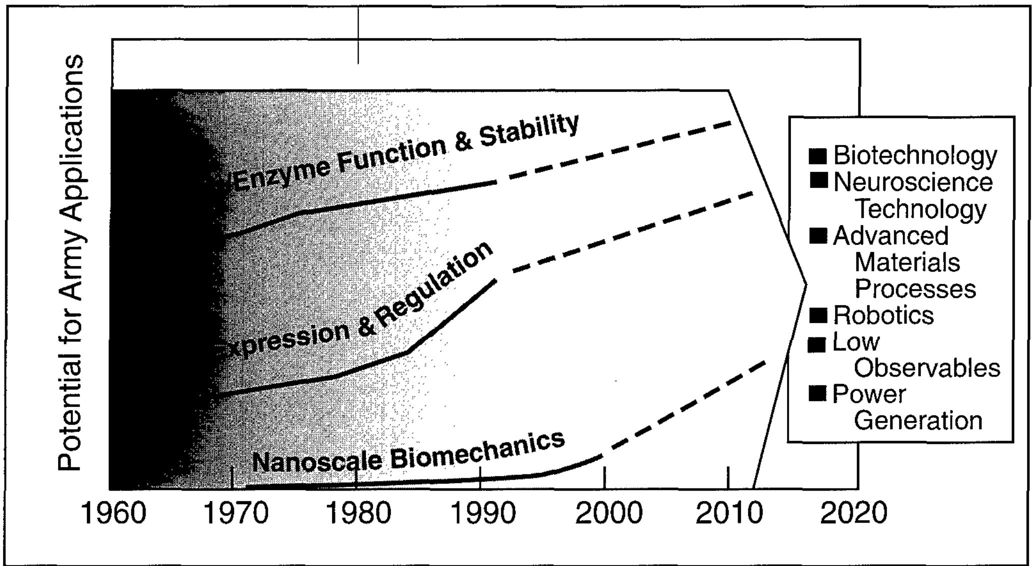
12. Behavioral, Cognitive, and Neural Sciences

a. Strategy

The Army Behavioral, Cognitive, and Neural Sciences (BCNS) program centers on the soldiers in units, and seeks a scientific understanding of the factors that can enhance or diminish human performance.

The research program is executed by two agencies, the U.S. Army Research Institute for the

Figure V-21. Materials from the biosciences are expected to have numerous military applications in the coming years.



Behavioral and Social Sciences (ARI) and the Human Research and Engineering Directorate of the Army Research Laboratory (HRED). Duplication of research is prevented through frequent meeting of the two agencies. Inter-Service coordination is effected through Reliance agreements. The research program is evaluated in the TARA review.

b. Major Research Areas

Basic BCNS research addresses two major topic areas:

- Cognitive Skills and Abilities (e.g., learning, memory, decision making, mental models)
- Perceptual Processes (e.g., hearing, vision, proprioception)

Cognitive Skills and Abilities—The goal of the cognitive skills and abilities program is to provide data, models, and theories to better understand how individuals learn and process information. An understanding of cognitive processes is essential to the optimal design of training programs and, ultimately, the human-systems interface. Several controllable factors influence the speed at which an individual learns. Other factors can influence the rate at which the trained skills are forgotten (see Figure V-22). Yet another set of factors significantly influences the ability of the individual to transfer skills learned under one set of conditions, such as a simulator, to slightly different conditions, such as real equipment. Results from this research are used to develop effective technologies for training soldiers. Effective training is defined by its cost, the permanence of the training, and its transferability to real equipment under realistic job conditions. The link between ARI and HRED research helps ensure that fielded systems are not only operable but also cost-effective.

Mean proportion of correct responses for the items given no mnemonic, a low mnemonic, or a high mnemonic on the pretest, posttest, and retention score. The results indicate that the use of mnemonics aids acquisition and retention of information (see Figure V-22).

The cognitive skills and abilities research thrust is also supported by research conducted at the Morris Brown College Center of Excellence for Research in Training (CERT). A unified program of experimentally based psychological research at that institute seeks to better understand mechanisms that permit individuals to better attend to key stimulus characteristics in the learning situation. Cognitive research will also support personnel selection and human-system interface design.

Overlearning produces reliably better retention of the skill than just training to proficiency. Even after thousands of practice trials, performance continues to improve. The results shown are from a meta-analysis of skill training research (see Figure V-23).

Perceptual Processes—The goal of the research program in perceptual processes is to better understand those processes, particularly as they impact on the use of head-mounted displays. This research will also support the Army's increasing emphasis on night operations, tele-operations,

Figure V-22. Mean proportion of correct responses as a function of pretest, posttest, and retention for items given no mnemonic, a low mnemonic, or a high mnemonic on the score. The results indicate that the use of mnemonics aids acquisition and retention of information.

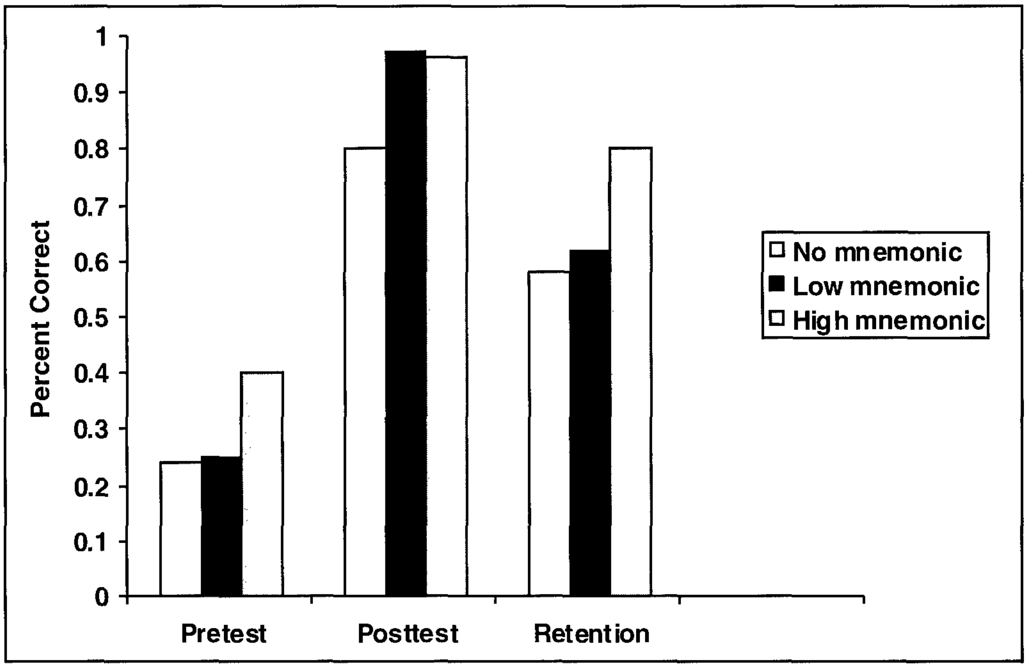
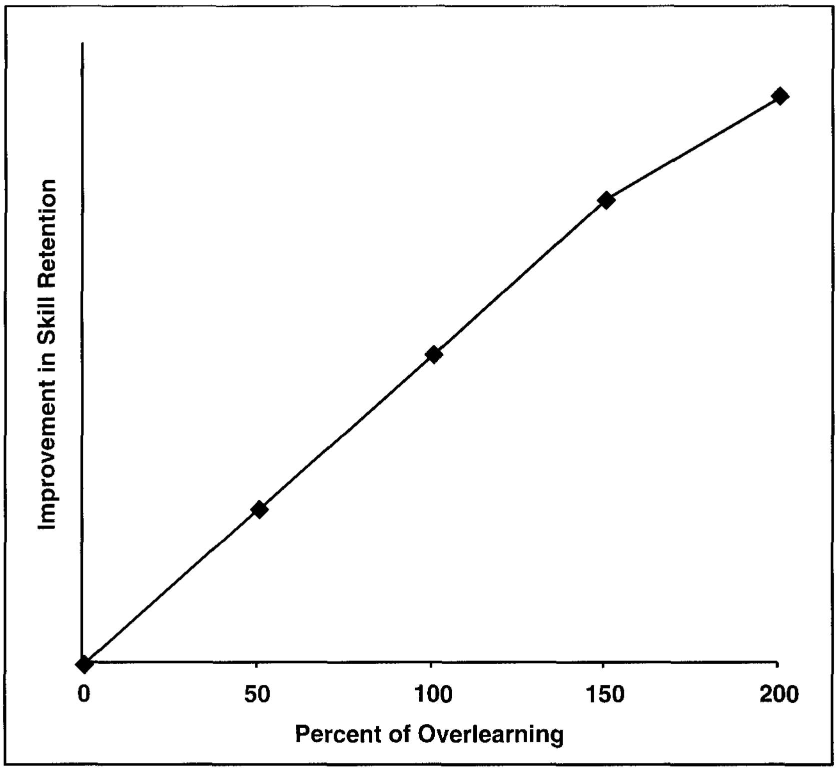


Figure V-23. Improvement in skill retention as a function of percent of overlearning



and the training and battlefield control systems afforded by advances in distributed interactive simulation. A better understanding of perceptual processes is needed if the Army is to effectively exploit advances in optics and infrared technologies. Well-designed human-equipment interfaces have been shown to be the key to permit effective individual utilization of new technologies.

c. Other Research Areas

Basic BCNS research also is concerned with:

- Noncognitive skills and abilities (e.g., stress, psychomotor, psychophysiological endurance)
- Leadership (e.g., development, skills, social structures)

Noncognitive Skills and Abilities—The goal of the research program in noncognitive skills and abilities is to address the issue of how various types of stress affect individual functions. Stress can result from high rates of physical or mental effort, physical exhaustion, or emotional response to threat. Although stress is a common response category for different causes, the actual stress responses are different in each case. Research is designed to address each type of stress with the eventual goal of developing effective training to offset the normally negative consequences of stress on behavior.

Leadership—The goal of the leadership research area is to understand the essentials of successful leadership performance and to use that understanding to develop effective training of leadership skills. The history of warfare has many examples of how seemingly less effective forces have prevailed in battle as a result of more effective leadership. Effective leadership includes the ability to manage others, coordinate activities, inspire a group, train individual and team tasks, and make decisions. The effective leader must also consider the environment in which he leads. That environment includes the culture of the organization and the organization's relative role in the general society itself.

d. Benefits of Research

The overall, eventual goal of this research is the optimization of human performance and the human-system interface. The "system" may be a weapon, communication network, other equipment, or a social entity such as in a command and control tactical operations center. Today's challenge is to both train soldiers and design the interface to their systems so that they can operate quickly and effectively under the conditions of the modern battlefield and other missions. The urgency of this research is compounded by the reality of a smaller force and an increased variety of possible missions.

Basic research in BCNS is the foundation upon which technological growth must be based if the Army is to meet its operational human factors, manpower, personnel, training, and system and equipment design requirements. A major objective is understanding cognitive and perceptual processing requirements of emerging military systems. For example, cognitive and perceptual information growth on the digitized battlefield already far outstrips human processing capacity. An effective research-based strategy to this problem is grounded in many of the BCNS domains. Additional knowledge in personnel selection, assignment, training, leadership, and effective interfaces will provide the means for the effective use of soldiers in new command and control structures. In the training area, research in the areas of computerized training, synthetic environments, and maturing artificial intelligence concepts will provide a basis for operating complex systems that route and prioritize battle information. These various research areas feed into the Human-Systems Interface and Manpower, Personnel, and Training technology areas described in Chapter IV.

An outstanding recent accomplishment of BCNS research was the integration of the naturalistic decision making model into the battle command doctrine. Results from this research have also been applied in several other areas by all of the Services and many civilian organizations. The unique environments in which military personnel must function and the extremely high performance levels that they must achieve make Army 6.1 research in the behavioral, cognitive, and social sciences necessary. Clearly, much of this research serves to improve the integration of soldiers with their jobs, units, environment, and equipment. The soldier must not only learn to cope, but to thrive in novel environments while interacting with new technologies. The in-depth understanding of these parameters of human performance is critical to effectively utilizing the growing technological opportunities that the Army is exploiting.

F.

Summary

The Army basic research program is an integrated in-house and extramural research program. The in-house laboratory programs are driven by mission needs; the extramural program is chartered to provide a balance between long-term extramural research foci—pursued through Army-funded academic Centers of Excellence and industry-led Federated Laboratories—and unanticipated, more forward looking research windows of scientific opportunity—pursued through the single investigator program. ARO and the management at the Army's research, development, and engineering organizations deliberate and coordinate in partnership to establish, implement, and meet overall Army research objectives. Despite receiving only a small portion of DoD's basic research budget, the Army derives the maximum return on investment from its research program through its high degree of integration. Figure V-24 depicts how the Scientific Research Areas described in this chapter support the 10 technology areas described in Chapter IV.

The research areas described in the preceding sections of this chapter are dynamic and continuously updated. Programs are reviewed by multi-Service organizations, by Army Battle Lab personnel, by peer reviews, and by coordinating groups established for each of the scientific areas. To illustrate this dynamic nature of the scientific areas, Table V-5 summarizes how certain research areas are receiving new or increasing emphasis and highlights recent accomplishments.

Much of the research supported by the U.S. Army is undertaken by distinguished scientists and engineers at American colleges and universities, as detailed in the Extramural Program section of this chapter. Not only does the Army benefit from the accomplishments of these people but they themselves receive honors bestowed upon them by their peers. Table V-6 summarizes some of the awards received during the past year by the individuals shown for their research sponsored by the U.S. Army.

The Army's science base is an essential foundation for the technology on which the Army's ability to meet future threats depends. Research for the Army is performed by a blend of university and in-house components that are uniquely suited to the Army's special requirements. Because of the fundamental role of the science base in shaping the Army's technological future, the Army is committed to strongly support basic research.

Figure V-24. Impact of Basic Research Areas on the Chapter IV Technology Areas

CHAPTER IV (6.2) TECHNOLOGY AREA	Mathematical Sciences	Computer and Information Sciences	Physics	Chemistry	Material and Information Sciences	Electronics Research	Mechanical Sciences	Atmospheric Sciences	Terrestrial Sciences	Medical Research	Biological Sciences	Behavioral, Cognitive, & Neural Scien
Aerospace Propulsion and Power				●	●		●					
Air and Space Vehicles		○			●		●					
Chemical and Biological Defense and Nuclear		○	○	●	○			●		●	●	
Individual Survivability and Sustainability	○		○	●	●		●			●	●	●
Command, Control, and Communications	●	●	●		○	●						●
Computing and Software	○	●	○		○	●						○
Conventional Weapons			●	●	●	○	●			○	○	
Electronic Devices			●	○	●	●					○	
Electronic Warfare/Directed Energy Weapons			●	○	○	●		●				
Civil Engineering and Environmental Quality				●	○		○	○	●	○	●	
Battlespace Environments								●	●	○		○
Human-Systems Interfaces (HSI)		○			○	○				●	●	●
Manpower, Personnel, and Training		○								●		●
Materials, Processes, and Structures		○	○	●	●	●	○				●	
Medical and Biomedical Science and Technology				○						●	○	○
Sensors		○	●		●	●		●	○	○	○	
Ground Vehicles					●		●					
Manufacturing Science and Technology	○	○	○		●	○					○	
Modeling and Simulation Technology	●	●				●		○	●			○

CHAPTER V (6.1) RESEARCH AREAS

● Significant Impact   ○ Some Impact

Table V-5. Illustrations of the Dynamic Nature of Research Programs

RESEARCH AREAS	NEW EMPHASIS	INCREASING EMPHASIS	ACCOMPLISHMENTS
MATHEMATICS AND COMPUTER SCIENCE	• Image analysis • Quantum computing	• Nano-technology	• Graph partitioner 10 times faster than state-of-the-art spectral methods • Geometric modeling, dynamic display & fast rendering techniques • Controllers for dynamic simulations of human/soldier systems
PHYSICS	• Dendritic Macromolecules • Microturbines & Thermophotovoltaics	• Diffusion & permeability in polymers • Chemical process modeling • Direct oxidation fuel cells • Chemical/biological detection	• Conduction via single quantum eigenstates in coulomb-blockaded quantum dots • Performance bounds for ATR • Elimination of optical self-focusing by population trapping • 3-D wire mesh photonic crystals
CHEMISTRY	• Mathematics of biological/natural systems	• Hybrid systems • Image analysis • Numerical methods for stochastic differential equations	• Environmentally friendly solvent/ chemical agent resistant elastomers • Mechanisms of CH bond oxidation in homogeneous catalysis • High aspect ratio etching of micro-turbine wheels • Enhanced chemical agent reactivity of layered nanoscale metal oxides • Complete hydrodechlorination of 1, 1, 1 trichloroethane & reduction of half mustard
MATERIALS SCIENCE	• Electroluminescent porous silicon • Molecular-based nanostructures • Dendrimer polymers (modeling/simulation)	• High performance fibers • Non-equilibrium processing • Biomimetic processing	• In-situ LCP/thermoplastic microcomposites • Flux-trapped superconducting magnets • diffusion-enhanced adhesion • Modulated diamond-like carbon films • High strength, tough microlayered polymer composites
ELECTRONICS	• Demining • Low energy electronics design for mobile platforms	• Optical control of array antennas • Image analysis & Terahertz electronics • Low power electronics with RF emphasis	• Multicarrier direct sequence code division multi access with lower bit error rate • First principles simulation using full band Monte Carlo • Field-controlled piezo-tuning of microdevices
MECHANICS	• Aerothermophysics for TMD missiles • Sensing, actuation, control for advanced engines • Real-time simulation of multi-body dynamics • Novel structural damping concepts • Reliability of structures/materials	• Advanced active control - rotocraft vibration & aeroacoustic coupling • High pressure hydrocarbon combustion • Composites in high strain rates • Damage mechanics	• Fast Floquet theory for computationally determination of a helicopter's stability in forward flight • First PLIF images of shock-initiated combustion in supersconic gas mixtures • Extension of shear band studies into 2D-velocity and rate of energy dissipation in moving adiabatic shear bands • First detailed mean and turbulence measurements in supersonic base flows with base bleed
ATMOSPHERIC AND TERRESTRIAL SCIENCES	• Terrain analysis & visualization • Landscape process dynamics	• Stable boundary layer • Acoustic signal variability in turbulent atmosphere • Terrain-vehicle interaction • Ice adhesion & mechanics (macroscale)	• Theory for turbulent scattering of acoustic waves in intermittent turbulence • Theory of dynamic drag law for high resolution atmospheric boundry condition • Development of CB aerosol detector • First generation, mathematically rigorous contact mechanics model for soil tire interaction • Prototype cone penetrometer system for in-situ measurements of hydraulic conductivity
MEDICAL	• Receptor-targeted drugs and antibodies • Oxygen free radical scavengers • Malaria Genone Project	• Genetic engineering • Microencapsulation of vaccines and drugs • Performance-enhancing nutrients	• Oral treatment (arteether) for drug-resistant malaria • Topical treatment (paramomycin) for cutaneous laishmaniasis • Diagnostic skin test for leishmaniasis
BIOLOGICAL SCIENCES	• Plant biotechnology • Response & adaptation to environmental signals • Enzymatic functions at extreme temperatures	• Biodegradative microbiology • Biodetection • Nanoscale biomechanics • Biocatalysis	• New detection signature for pathogenic bacteria • Isolation of genes required for establishing and maintaining hibernation • Crystal structures of gene repressor and its complexes • Incorporation of non-natural amino acids into artificial proteins
BEHAVIORAL, COGNITIVE, AND NEURAL SCIENCES	• Perceptual processes • Attention fixation	• Night vision • Long term skill retention • Multi-modal interfaces	• Depth perception cue isolation and enhancement • Determined role of commitment to performance

Table V-6. Some of the Awards Received During the Past Year by Scientists and Engineers for Research Sponsored by the U.S. Army

INDIVIDUAL	AFFILIATION	AWARD RECEIVED
Baer, Prof. E.	Case Western Reserve Univ	1996 Paul S. Flory Award
Bancroft, COL W. H.	Army Medical, Research & Materiel Command	AMSUS Corgas Medal
Baum, Prof. C.	Clemson Univ	1996 IEEE Browder J. Thompson Prize Award
Belytscho, Prof. T.	Northwestern Univ	Technical Achievement Award, NAS
Bourne, Prof. L.	Univ of Colorado	President, Federation of Behavioral, Psychological, and Cognitive Sciences
Bras, Dr. R.	MIT	Bacardi & Stockholm Water Foundation Professor
Brockett, Prof. R.	Harvard Univ	1996 SIAM W.T. & Adalia Reid Prize
Burke, COL D.S.	Walter Reed Army Inst of Research	President, American Society of Topical Medicine & Hygiene
Conrad, Prof. J.	Univ of Wisconsin	Byron-Byrd Award for Excellence in Research
Datta, Prof. S.	Purdue Univ	IEEE Fellow
deBoor, Prof. C.	Univ of Wisconsin	Society of Industrial & Applied Mathematics John Von Neuman Award
Druckman, Dr. D.	National Research Council	Otto Klineberg Intercultural & International Relations Award
Dutton, Prof. R.	Stanford Univ	1995 IEEE Jack A. Morton Award
Erdogan, Prof. T.	Univ of Rochester	1995 Adolph Lomb Medal of OSA
Frechet, Prof. J.	Cornell Univ	ACS Award in Applied Polymer Science
Fujimeto, Prof. J.	MIT	IEEE Fellow
Gersbacher, Prof. M.	Univ of Wisconsin	AAAS Fellow
Hall, Prof. H.	Univ of Arizona	ACS Award in Polymer Chemistry
Happer, Prof. W.	Princeton Univ	National Academy of Science
Haus, Prof. H.	MIT	1995 National Medal of Science
Hess, Prof. K.	Univ of Illinois	1995 IEEE David Sarnoff Field Award
Houde-Walter, Prof. S. N.	Univ of Rochester	Fellow of the Optical Society of America
Ishamaru, Prof. A.	Univ of Washington	1995 IEEE Antennas and Propagation Society Distinguished Achievement Award
Izatt, Prof. R.	Brigham Young Univ	ACS Award in Separations Science & Technology
Kailath, Prof. T.	Stanford Univ	1996 IEEE Donald G. Fink Prize Award
Kriksunov, Dr. L.	Pennsylvania State Univ	International Society of Electrochemistry Tajima Prize
Lavernia, Prof. E.	Univ of California—Irvine	1996 ASM Silver Medal Award
Lawier, Prof. J. E.	Univ of Wisconsin	1995 Penning Award
Leburton, Prof. J-P	Univ of Illinois	IEEE Fellow
Leger, Prof. J.	Univ of Minnesota	Fellow of the Optical Society of America
Leone, Prof. S.	JILA	National Academy of Science
Maragos, Prof. P.	Georgia Inst of Technology	IEEE Fellow; 1995 IEEE W.R.G. Baker Award
Mazur, Prof. E.	Harvard Univ	1996 Invited Paper, Nobel Symposium
Nirenberg, Prof. L.	N.Y. Univ—Courant Institute	National Medal of Science
Papaefthymiou, Prof.	Yale Univ	Best Paper Award, 32nd ACM/IEEE Design Automation Conference
Parhi, Prof. K.	Univ of Minnesota	IEEE Fellow
Rao, Prof. C. R.	Pennsylvania State Univ	National Academy of Science
Revelle, Prof. W.	Northwestern Univ	AAAS Fellow
Sastry, Prof. S.	Univ of California—Berkeley	IEEE Fellow; ACC Echman Award
Sethuraman, Prof. J.	Florida State Univ	Fullbright Scholar
Smith, Prof. H.	MIT	1995 IEEE Cledo Brunetti Award
Varadham, Prof. S.R.S.	N.Y. Univ—Courant Institute	National Academy of Science
Weaver, Prof. J.	Univ of Minnesota	1995 Humbolt Award
Weinstein, Prof. R.	Univ of Houston	1995 Materials Research Society Performance Award
Yablonwitch, Prof. E.	UCLA	1995 R.W. Wood Prize of OSA
Yates, Prof. J.T.	Univ of Pittsburgh	National Academy of Science
Zadeh, Prof. L.	Univ of California—Berkeley	1995 IEEE Medal of Honor
Zinn, Prof. B.	Georgia Inst of Technology	1996 AIAA Propellant & Combustion Award

CHAPTER VI

Infrastructure

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CHAPTER VI

Infrastructure

A major element of the Army strategy for military technology is a strong, viable in-house research capability. Laboratories and research, development, and engineering centers (RDECs) are the key organizations responsible for technical leadership, scientific advancement, and support for the acquisition process. The organizational structure of the current Army Science and Technology program is illustrated in Figure VI-1, the funding breakdown by organization is shown in Figure VI-2, and the geographical locations of research sites are shown in Figure VI-3. Science and Technology Objectives related to this chapter are contained in Volume II, Annex A.

A. INTRODUCTION

The Army is committed to maintaining world class research, development, and testing facilities. We equip these facilities with modern equipment and hire and retain personnel capable of utilizing the tools provided. This infrastructure is committed to meeting the developmental needs of the land combat force for the foreseeable future and will provide for the effective transfer of developing technologies to the civil as well as the military sectors.

Figure VI-1. Army S&T Organization

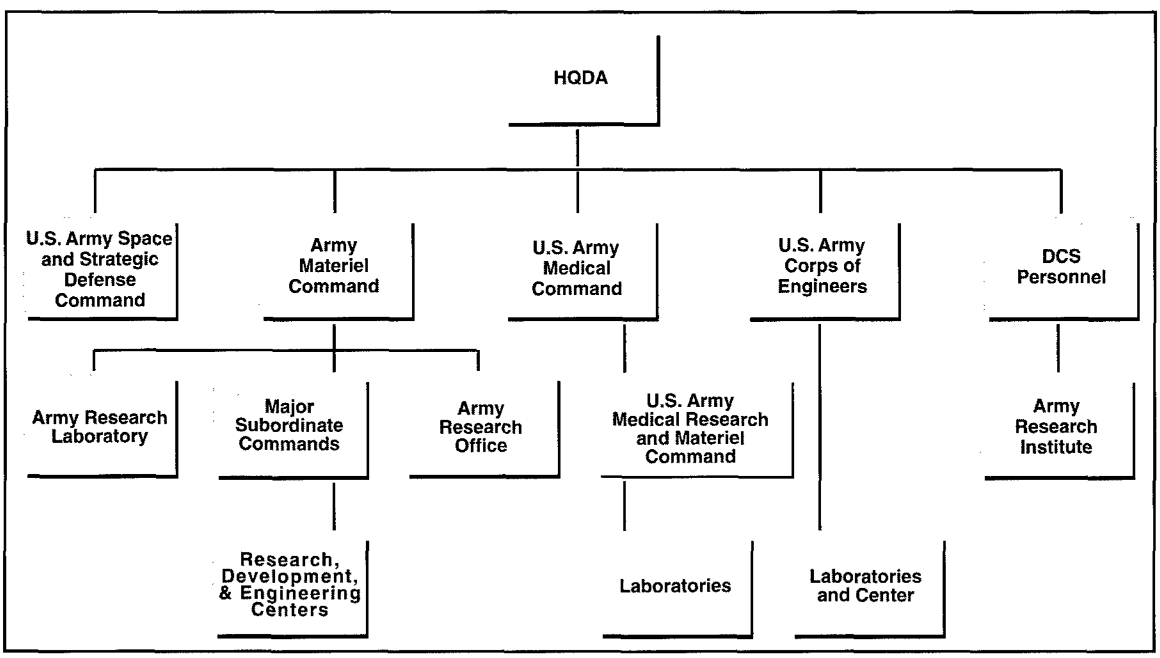


Figure VI-2. Army S&T Funding Distribution, FY97 Army Budget

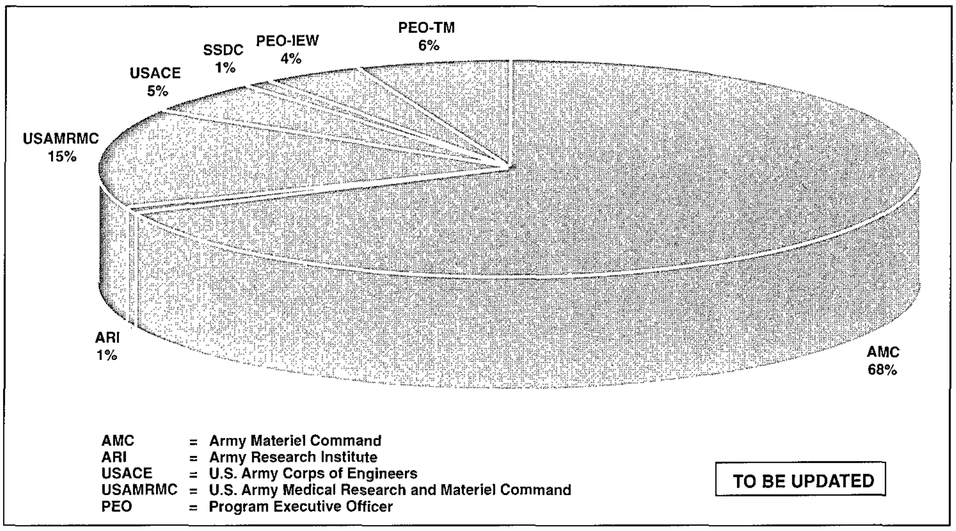
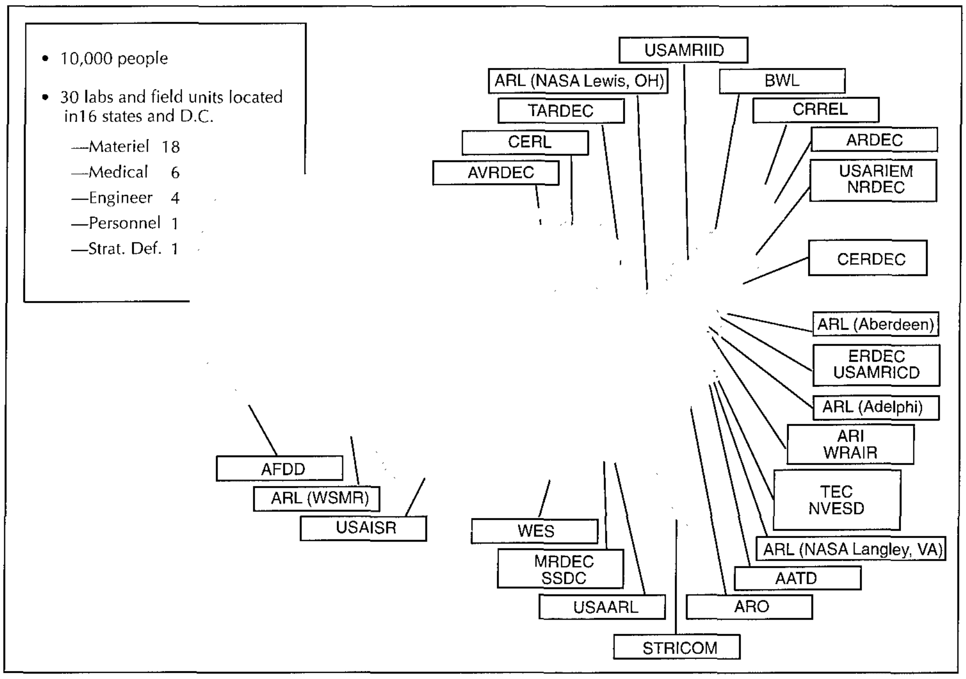


Figure VI-3. Army R&D Involved in S&T Resources, FY96



Chapters III through V outline what the Army plans to accomplish in terms of science, technology, and development to meet the Army's future warfighting needs. How well this is accomplished depends largely on the ability of management to apply state-of-the-art scientific tools, equipment and facilities, and personnel resources in meeting the stated goals.

Keeping the infrastructure current demands an investment, in dollars and management effort, consistent with the needs of the materiel, combat, and training development communities for fielding weapon systems and with the user community's training and operational needs. It also involves internal investment in S&T to provide added technology to meet simulation and modeling objectives. The STOs in Volume II will enhance our ability to support materiel development and support advances in gaming and modeling battlefield operations and doctrine.

B. STRATEGY

The Army will continue a multifaceted approach to support and maintain its infrastructure. Appropriated funds will be used to construct, purchase, and maintain unique equipment and facilities. Equipment items or facilities which are developed during a specific program are retained and modified, as appropriate, to meet additional R&D needs. The Army will continue to expand simulation and modeling capacities to reduce costs of materiel development, improve safety, and shorten developmental schedules. Simulation and modeling is included in all ATDs in Simulation Support Plans. Finally, the Army leverages the facilities investments of external organizations by sharing or otherwise using those facilities that can contribute to Army objectives.

C. THE ARMY'S SUPPORTING INFRASTRUCTURE

The Army's supporting R&D infrastructure consists of (1) physical facilities and equipment; (2) distributed interactive simulation; (3) software; (4) communications systems; (5) personnel; and (6) management initiatives. This chapter addresses the capabilities in each of these areas in place at Army installations, as well as those available to the Army through working relationships with other organizations. Examples of successful operations are presented, along with descriptions of how the Army has benefited. Also highlighted are Army plans to enhance and improve existing capabilities through prudent investment and leveraging.

1. Federated Laboratory Initiative

ARL instituted the federated laboratory concept in FY95. The federated laboratory initiative is a unique combination of the best features of the government and private sectors. Chapters V and VII provide more detail on federated laboratories.

2. Physical Facilities and Equipment

This subsection discusses facilities and equipment available to the Army to carry out its science and technology mission. It includes physical plant; facility consolidation; facility modernization; facility upgrade strategy; facilities shared with other organizations, inside and outside the DoD; ranges and testing facilities; and special equipment and computer resources.

a. Physical Plant

The Army has invested significant resources in special facilities, ranging from small, uniquely designed, state-of-the-art laboratories such as the Corps of Engineers' Ice Engineering Laboratory to large-scale facilities using sophisticated instrumentation required to measure and support the evaluation of myriad system prototypes and weapon systems under development, such as those located at Aberdeen Proving Ground. Many facilities have been developed in partnership or under a leveraging agreement with other services, government organizations, industry, or academia.

The Simulation, Training, and Instrumentation Command (STRICOM) is located in a modern facility in Orlando, Florida. The command is collocated with the Naval Air Warfare Training Systems Division. STRICOM, the Navy command, the University of Central Florida's Institute for Simulation and Training, and many local defense contractors, are making Orlando the center of DoD simulation activities.

The Army Research Laboratory is continuing the upgrading process to accommodate consolidations and incoming R&D activities, which are relocating under the 1991 Base Realignment and Closure (BRAC) Commission decision. Construction at Aldephi Laboratory Center (ALC) will accommodate the BRAC91-mandated relocation of functions from White Sands Missile Range, New Mexico; Fort Monmouth, New Jersey; and Fort Belvoir, Virginia.

Several projects make up the total construction program, which will add approximately 320,000 square feet to the installation at a cost of $77 million. The largest of the projects is the $60 million Physical Sciences Building, which will house the Sensors and Electron Devices personnel relocating from Fort Monmouth, New Jersey; the Sensors Directorate, relocating from Fort Belvoir, Virginia; and the Advanced Simulation and High Performance Computing (ASHPC) Directorate. The R&D computer center will allow the ASHPC Directorate to tie to the high-performance and simulation computers located at Aberdeen Proving Ground.

Completion of the Physical Sciences Building is scheduled for July 1998. The recently completed, high-bay facility accommodates the Information Science and Technology Directorate's research in atmospheric science. It provides loading, transfer, and testing capabilities of special meteorological field research equipment. This facility houses 8,055 square feet of laboratory/high-bay space and 2,109 square feet of offices. ALC construction also includes a modification of the current heat-chill plant to accommodate the increase of facilities.

Construction at Aberdeen Proving Ground (APG) includes a Materials Research Facility, Out-of-Laboratory facility, and the Target Assembly and Storage Facility. The new Materials Research Facility at APG was authorized in 1994. It will accommodate the ARL material scientists and engineers of the Weapons and Materials Research Directorate—many of whom were formerly from Watertown, Massachusetts, and Fort Belvoir, Virginia. This $80 million facility will support a wide range of basic materials research and other defense, government, and private agency customers. Occupancy of the facility is scheduled for June 1997.

Construction began in 1995 on an Out-of-Laboratory facility that would provide electromagnetic pulse survivability and vulnerability analysis and testing capabilities for all of DoD. Vulnerabilities are found through exposure to low-level fields and then verified with current injection devices. The Out-of-Laboratory facility will house the fabrication of the current injection devices and subsequent system testing. The facility is expected to be completed in 1996.

The Target Assembly and Storage Facility, on the north end of Spesutie Island at APG, was completed in July 1996. It houses the assembly and storage of classified targets and also provides the specialized capability to work with heavy-metal armor such as depleted uranium.

The U.S. Army Space and Strategic Defense Command (USASSDC) operates and/or funds several support capabilities that offer unique opportunities for enhancing Army science and technology with data and information derived from assessments, analyses, evaluations, experiments, and tests of both strategic and tactical systems. The Advanced Research Center is a contractor-operated computer facility located in Huntsville, Alabama, which contains a variety of government-owned hardware resources. These consist primarily of general purpose application development processors that provide a wide range of architectures. These resources can be configured to support a variety of experiments and developmental activities. The Simulation Center provides computer time for over 600 scientists and engineers to perform computationally intensive tasks such as investigating nuclear optical and radar system effects, optical signature codes, and computational fluid dynamics codes. The command also houses a Digital Emulation Technology Laboratory which specializes in the design and utilization of parallel processing techniques.

The Edgewood Research, Development, and Engineering Center (ERDEC) maintains surety agent research facilities to support the Army's chemical and biological defense programs. The laboratories are fully equipped with security measures, fume hoods, and exhaust filtration units to perform work with highly toxic materials for research and product acceptance purposes. Analogous facilities for investigating medical countermeasures are found at the U.S. Army Medical Research Institute of Chemical Defense. Having these facilities at the same installation reduces duplication of effort and administrative costs generated by the particularly sensitive nature of the products stored and handled. The Nuclear Magnetic Resonance Laboratory is the only such facility in the United States certified to work with chemical surety materials and is used to identify agents, degradation products, and impurities.

The U.S. Army Communications-Electronics Command (CECOM) Research, Development, and Engineering Center (RDEC) has a dynamic integrated facility that can be rapidly reconfigured to replicate diverse existing and evolving tactical Command, Control, Communications, and Intelligence/Electronic Warfare (C3I/EW) battlefield environments. The Digital Integrated Lab/Testbed enables and facilitates comprehensive evaluations of new prototypes, evolutionary system developments, new technologies, commercial products, and systems interoperability. It interfaces with the Battle Labs supporting Advanced Technology Demonstrations (ATDs) and Advanced Warfighting Experiments (AWEs), field sites, contractor testbeds, and simulations staffed with technical engineering experts at all these facilities. The Digital Integrated Lab/Testbed is a fundamental component for systems engineering and integration focusing on battlefield intelligence, surveillance, situational awareness, combat ID, targeting, and battle damage assessment. External sites that are connected to the Digital Integrated Lab/Testbed via the Army Interoperability Network (AIN) and the Defense Simulation Internet (DSI) include:

- Battle Command Battle Labs at Fort Gordon, Georgia, and Fort Leavenworth, Kansas
- Army Battle Command Systems (ABCS) Laboratory, Fort Monmouth, New Jersey
- Joint Interoperability Test Center, Fort Huachuca, Arizona
- Technology Integration Center, Fort Huachuca, Arizona
- Other government and contractor locations

The Virtual Prototyping Infrastructure at the U.S. Army Tank-Automotive Research, Development, and Engineering Center (TARDEC) is revolutionizing the military ground vehicle development process. This new initiative will develop and demonstrate a synergistic, distributed virtual prototyping activity that will integrate and interface advanced concepts in mobility, survivability, electronics, lethality, command and control, design, and manufacturing into any phase of a system. These activities support numerous ATDs and AWEs. The TARDEC Virtual Prototyping facilities include:

- Vetronics Simulation Laboratory
- Survivability Technology Laboratory
- Virtual Mock-up Facility
- Vetronics Integration Laboratory
- Software Engineering Laboratory
- Signature Laboratory
- Applied Engineering Laboratory
- Physical Simulation Laboratory
- Armor Integration Laboratory

b. Facility Consolidation

In addition to the consolidation of major S&T elements into ARL, S&T activities of the RDECs are also undergoing consolidation, some because of BRAC decisions and others in the quest for further efficiencies. Pursuant to BRAC 93, five business areas of the disestablished Belvoir RDEC have been reassigned to TARDEC. About half have relocated to Warren, Michigan, into reconditioned office space. New laboratories for water purification are under construction and will open in December 1996.

c. Facility Modernization

Changes in technology and its application to solving Army problems make it necessary to upgrade S&T facilities.

The Joint Precision Strike (JPS) Integration and Evaluation Center (IEC) at the Topographic Engineering Center (TEC) uses wideband and tactical communications links (e.g., FAST, Trojan Spirit, TACSAT, Global Grid, T-1 lines, video teleconferencing, and DSI networking) to provide connectivity with live and simulated exercises to support Army precision strike training and contingency planning activities across CONUS and OCONUS. This distributed simulation capability is the primary mechanism for Army precision strike and survivable armed reconnaissance experimentation, training, and contingency planning. The IEC provides control, data collection, environment and system simulation, and presentation/visualization support for JPSD and acts as the central hub of the demonstration network. The network includes existing links to the D&SABL, the BCBL-H, DARPA, and the Army Aviation Test Bed; links to Fort Hood and MICOM are being implemented.

The IEC was the site of a major demonstration to the Chief of Staff, Army, of emerging technologies which support the implementation of the information army concept. The demonstration clearly revealed that the rapid generation of digital terrain data would be a key element in meeting long-term Army developmental and operational goals. The results of this and other demonstrations have led to the development of the Rapid Battlefield Visualization–Advanced Concept Technology Demonstration (RBV–ACTD) for rapid mapping and terrain visualization.

Phase I of construction has been completed on a facility that will enable the Walter Reed Army Institute of Research (WRAIR) to vacate the substandard converted classroom building it has occupied since 1923. WRAIR will be located in a new facility that will provide 475,000 square feet of state-of-the-art medical research and development laboratory for the missions of WRAIR and the Naval Medical Research Institute (NMRI). Planned for a staff of 850 and at a cost of $147.3 million, the new facility will be located in the Forest Glen section of the Walter Reed Army Medical Center in Silver Spring, Maryland. The decision to locate the new lab in the Forest Glen section of Walter Reed was based on the availability of a long-term site adjacent to six current WRAIR buildings. This allows the new laboratory to be about 20 percent smaller than if it were built elsewhere.

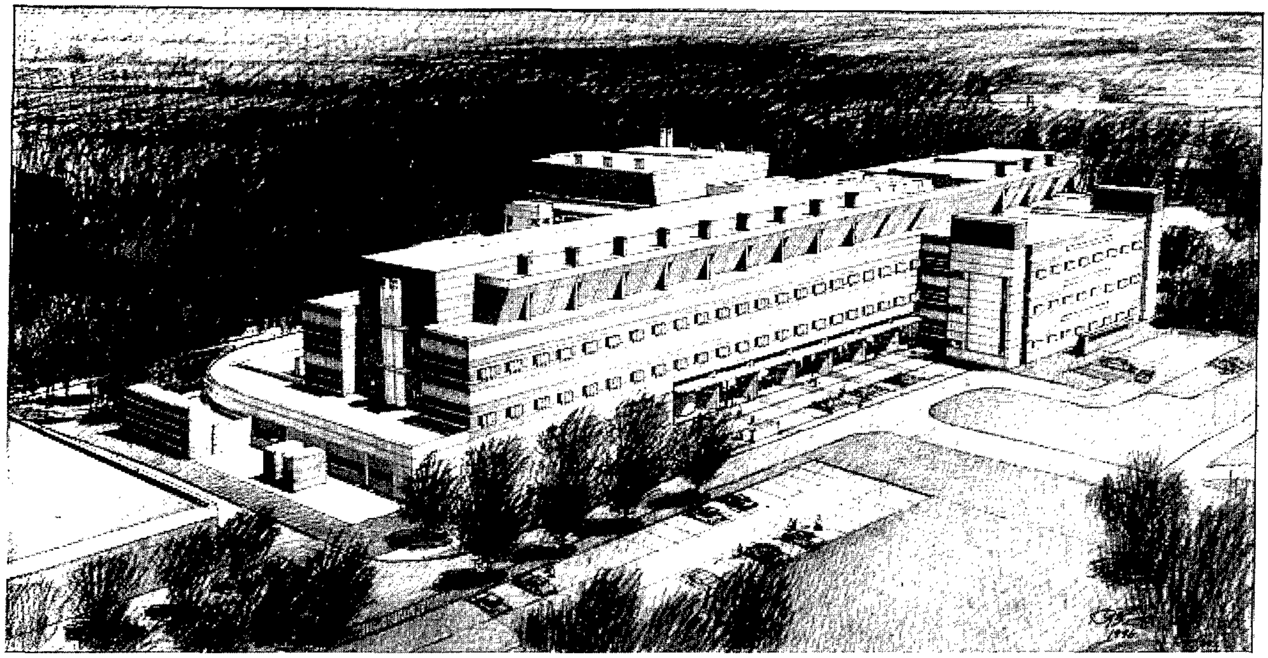
The new building (Figure VI-4) will have a below-ground, self-contained animal facility; three floors above ground for laboratories, offices, and research activities; and a full-filtered, non-recirculating air system. Laboratories and scientist offices will be organized in standard-sized modules that, combined with a between-floors utility distribution system, will provide maximum flexibility to accommodate current and future military medical research and development as program evolution and consolidation continues.

The laboratory will be unusually efficient compared with civilian biomedical R&D facilities. Both the space per occupant and the construction cost per unit area will be below national norms. The new lab's final total area will be nearly 10 percent less than is currently available at WRAIR and NMRI, but this will be offset by a much improved floor plan of labs, support spaces, and offices. With the opening of this magnificent facility, planned for 1999, military medicine will finally have a state-of-the-art facility to house its cutting edge research programs and highly skilled personnel. It will allow WRAIR and NMRI to remain key resources able to respond to emerging biomedical threats throughout the 21st century.

The tri-chamber altitude facility at U.S. Army Research Institute of Environmental Medicine (USARIEM) has been enhanced to a fully computerized, environmentally controlled chamber, man-rated at 50,000 feet, capable of supporting long-term, live-in studies with complete metabolic monitoring. This facility is a unique national asset for studying human performance at extremely high terrestrial altitudes.

Co-location of Army medical R&D facilities and equipment at Armstrong Laboratories, Brooks Air Force Base, created a unique facility available for use by DoD investigators studying the bioeffects of electromagnetic radiation. The combination of two high power microwave emitters and large anechoic chambers permits directional control of sources and sensitive assessment of absorption. This state-of-the-art medical research facility will substantially advance the development of exposure standards and protective devices.

Figure VI-4. New Walter Reed Army Institute of Research (WRAIR) Facility Planned for 1999



Unique biological containment facilities at the U.S. Army Medical Research Institute for Infectious Disease have been extensively renovated. These laboratories are a critical national asset and are frequently called on to support civilian health authorities in characterizing unknown diseases such as the recent Hantavirus outbreak in the southwestern United States.

A human biomechanics laboratory has been established as a joint effort between the Natick Research, Development, and Engineering Center and the U.S. Army Research Institute of Environmental Medicine. This facility allows for world-class research concerning strength, endurance, and load-carrying capabilities of U.S. soldiers.

Exciting new rapid prototyping capabilities are being integrated into several of the RD&E centers. Whether Stereolithography, Laminated Object Manufacturing, or other, this new capability is greatly enhancing the visual output of the concept formulation process while using the actual 3-D CAD model. At TARDEC, prototype parts to manufacture vehicles are automatically produced from drawings.

d. Strategy for Facility Upgrades

Upgrading S&T facilities requires a judicious mix of renovation and new construction to assure that the best use is made of facilities funds. As yearly plans are prepared, a close look at existing facilities is conducted to determine if extensive modifications, above those which are possible using mission funds, are required to carry out future plans. An early decision must be made between renovation, which takes a portion of the existing plant out of operation for a period of time, and new construction. The review process involves a number of agencies to assure that all factors are taken into consideration: can the activity be relocated to other space which will be available at a lower cost than new construction; can the task be passed to another S&T organization which has manpower skills and space to perform the work under a cooperative memorandum of understanding; do government elements outside the DoD have the capacity to perform the work in lieu of expanding an Army facility; would the effort be better performed outside the government in a Federally Funded Research and Development Center (FFRDC) or industry? The high cost of new construction can make these alternatives very attractive. The final decision within the Army rests with the laboratory director, the supporting MACOM, the DA staff, and ultimately the Secretary of the Army. Outside reviews by DoD, OMB, and the Congress assure that funds appropriated for major modifications or new construction are wisely invested.

e. Shared Facilities

The Army makes extensive use of facilities controlled by other government organizations. Following are a few examples.

Facilities Shared with NASA

The Army has collaborated with NASA for over 20 years in three areas of vital interest to the Army. Crash damage simulation, testing, and evaluation programs are conducted jointly at the Langley Impact Dynamics Research Facility. Rotor vibration and marginal stability issues are pursued at the Langley Transonic Dynamics Tunnel, where heavy gasses, rather than air, are used to safely address the issues associated with real world test environments.

Aeromechanics issues such as flight dynamics, handling qualities, and crew station design human factors are studied by NASA and Army scientists at the Ames Research Center. A suite of wind tunnels ranging from the AFDD's 7- x 10-foot tunnel to NASA's 40- x 80- x 120-foot Full Scale Tunnel, the Numerical Aerodynamic Simulator, Vertical Motion Simulator, Man-Vehicle Systems Research Facility, Automation Sciences Research Facility, and U.S. Army Aviation and Missile Command's Crew Station Research and Development Facility, along with aircraft resident at the Center, provide a unique and synergistic environment for scientific and engineering advancement. Rotorcraft available to support research include the Flying Laboratory for Integrated Testing and Evaluation (FLITE) (NAH-1S with Apache visionics), UH-60 Blackhawk for airloads studies, the joint NASA/Army UH-60 Rotorcraft/Aircrew Systems Concepts Airborne Laboratory (RASCAL), and a UH-1.

The CECOM RDEC Command and Control Systems Integration Directorate (C2SID) and NASA have formed a Joint Research Project Office (JRPO) at NASA Langley, Virginia. The Army is leveraging heavily on NASA to do work on controls and displays, primarily for aviation but with applications to all platforms.

Army Collaboration with Academia

The Army's Armament Research, Development, and Engineering Center has developed an in-house electric gun facility, the Electric Armaments Research Center (EARC) (Figure VI-5). The Institute for Advanced Technology was established at the University of Texas in 1990 with a critical research capability in electromechanics and hypervelocity physics. The Center has achieved significant intellectual and collegiate collaboration from the full spectrum of facilities at the University of Texas-Austin, especially the Center for Electromagnetics. It also exploits the capabilities of the EARC and Defense Special Weapons Agency's Green Farm Test Facility. After laboratory tests and development, the electric gun will be range tested at the new electric gun test facility at Yuma Proving Ground.

The Army Research Laboratory provides overall technical and contractual oversight for the Army High Performance Computing Research Center (AHPCRC) initially established at the University of Minnesota, assisted by Purdue, Howard, and Jackson State Universities—the latter two being historically Black institutes of higher learning. The computational facilities at the AHPCRC provide university and Army researchers a unique opportunity to explore challenging computational models which until now, were either impossible or infeasible.

The High Energy Laser System Test Facility (HELSTF), managed by USASSDC, is a tri-Service facility with representatives from the Navy and Air Force on site. The Mid-Infrared Advanced Chemical Laser (MIRACL) is the workhorse laser for the site and the only high energy laser operating in the free world. The associated Sea Lite Beam Director (SLBD) is the only laser beam director capable of transmitting a high energy laser beam. The SLBD provides extremely high pointing and tracking accuracies required for near earth orbit object tracking.

f. Ranges

As environmental issues become more prominent, the use of modeling and simulation will consume a larger portion of the S&T budget. There are, however, certain activities which require testing on ranges before they can be recommended for development. One example of a needed S&T range is the Large Blast Thermal Simulator being built by the Defense Special Weapons Agency (DSWA) at the White Sands Missile Range. This will be a unique facility for testing combined thermal radiation and airblast nuclear weapons effects (Figure

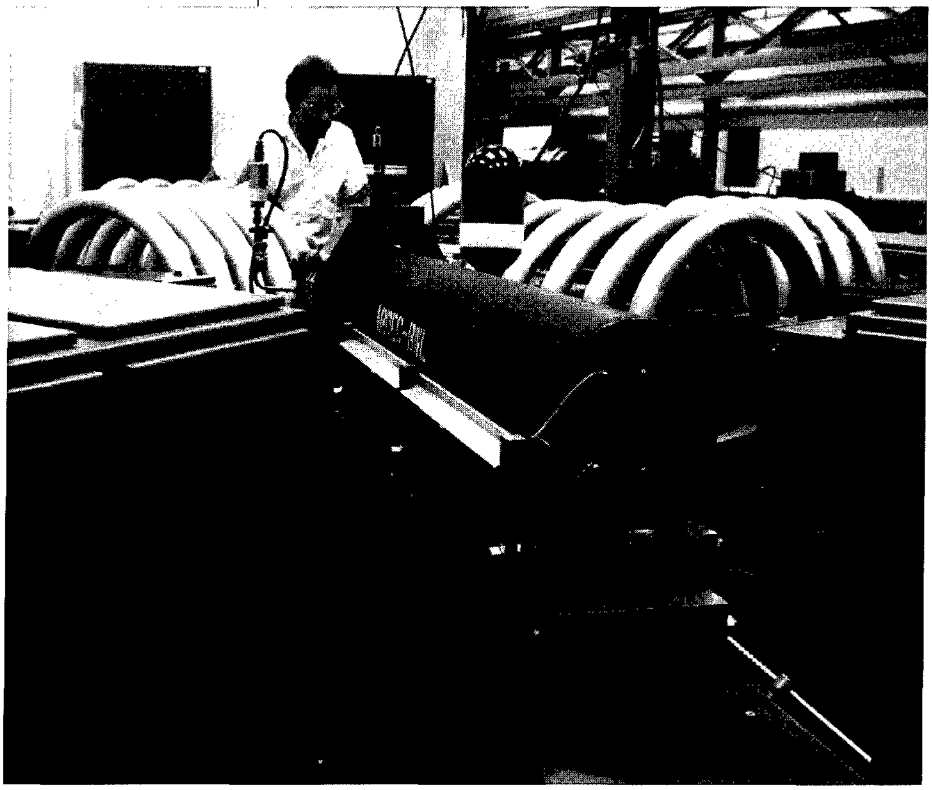


Figure VI-5. Electric Gun concepts are evaluated using unique armament test facilities.

VI-6). This facility is the result of a cooperative program between the Army nuclear survivability technology base program and DNA over the past 11 years. At 20 meters in diameter and 240 meters long, it will be twice the size of the next largest tube, which is located in France.

Another example is the Test Range Facility for Advanced Aerospace Vulnerability facility recently completed by the ARL. It is a modernized aircraft and missile vulnerability/lethality test facility that will not only enable increased test output, but will also expand existing capabilities and provide new capabilities to test and assess vulnerabilities to a complete range of ballistic weapons. It is particularly well suited for the conduct of congressionally mandated live-fire tests of Army aircraft, missiles, and anti-air weapons.

Kwajalein Missile Range (KMR) is a major range and test facility base managed by USASSDC for the DoD. KMR supports strategic and theater missile defense research and technology validation programs for the Army and the Ballistic Missle Defense Office, as well as strategic offensive weapons system development and operational testing conducted by the Air Force and Navy. KMR also assists in tracking and monitoring NASA space missions and provides deep-space tracking for the U.S. Space Command. The facility offers a multiplatform network of data gathering devices, providing a diverse mixture of radar, optical telemetry, and scoring sensors to observe and record data for reentry vehicles. These devices also accumulate target signature data for ballistic missile applications.

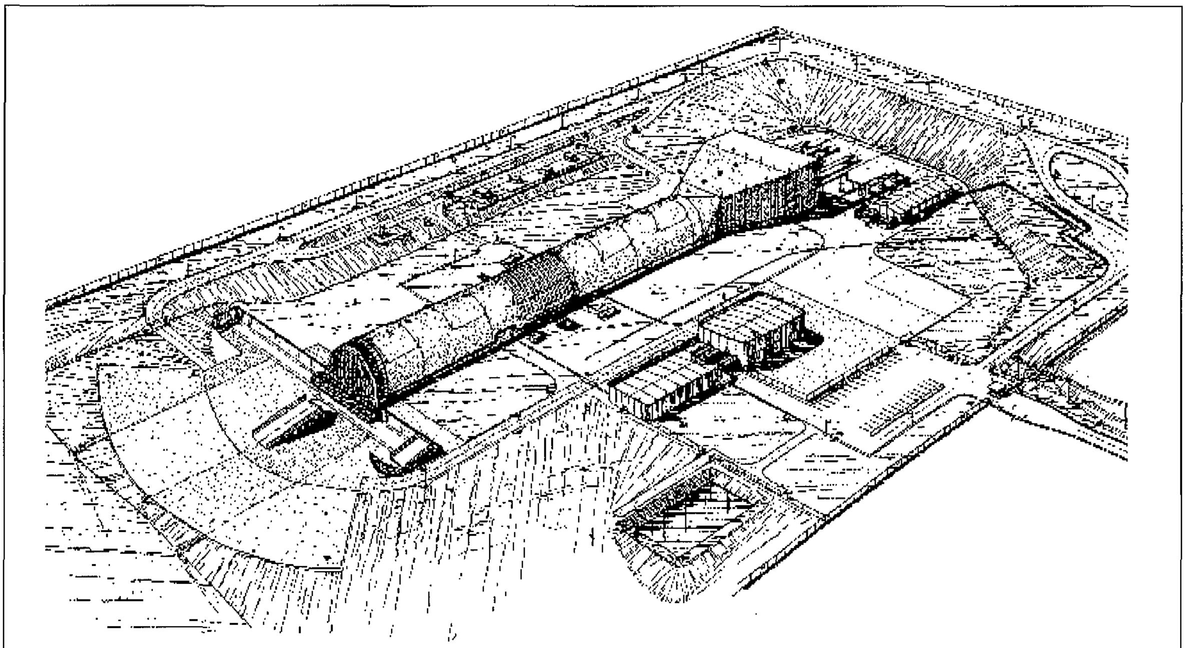
A final example is the Army Missile Optical Range, a compact laser radar range located at the Aviation and Missile Command. It serves as an experimental facility supporting laser and laser radar measurements of selected materials targets, having the capability of obtaining total cross section measurements, highly resolved doppler data, and full-scale target measurements.

g. Specialized Equipment

Special research needs call for special facilities in the pursuit of excellence. The Army has invested substantially in sophisticated special-purpose items such as those detailed below.

Several Army laboratories and centers have acquired molecular beam epitaxy equipment for use in growing new semiconductor device structures with atomic dimensions. This technology has broad application to a range of Army requirements, such as the need for electro-optical sensor materials with higher resolution and greater sensitivity, and signal processing devices with higher speed and greater throughput capability.

Figure VI-6. Large Blast/Thermal Simulator



The ion implantation facility at the ARL (Figure VI-7) provides a unique, state-of-the-art capability for the development and demonstration of novel ion surface treatments and coating techniques for Army materiel such as machine tools and parts subject to corrosive or high wear environments.

ERDEC has a one-of-a-kind scanner which utilizes light beam profiling technology with a newly developed laser alignment system to generate a three-dimensional, digitized surface contour of the human head consisting of 600,000 data points. If desired, the data can be transferred to a numerical control cutting machine to generate a model of a head. This capability is used for anthropomorphic assessments related to the development of chemical-biological respirators such as sizing, anatomical dead space volume, dynamic changes in individual facial configuration with time, and variation in facial configuration between individuals. Recent modifications have enhanced its capability while drastically reducing computational time.

3. Distributed Interactive Simulation

The DoD Science and Technology Strategy places strong emphasis on "synthetic environments." The Army's Distributed Interactive Simulation (DIS) initiative provides the lead for coordinating and integrating tri-Service, DARPA, and Defense Modeling and Simulation Office (DMSO) activities toward advancing the underlying open architecture, standards, data bases, and general purpose designs necessary for achieving seamless synthetic environments. Through use of the DARPA-established Defense Simulation Internet (DSI) as the backbone for computer communication services, a wide array of simulation and modeling capabilities located at multiple facilities can be linked to form synthetic environments ranging in scale and resolution suited for a variety of uses (see Figure VI-8).

These environments bring developers, scientists, engineers, manufacturers, testers, analysts, and warfighters together to address and solve their most pressing problems. Near-term efforts are using and expanding current capabilities to support science and technology demonstrations and the initial capability for Army Training and Doctrine Command (TRADOC) Battle Laboratories. Experience gained from these activities will evolve into new methodologies for the continuous evaluation and evolution of concepts and requirements in a joint task force and combined arms battlefield context with soldiers-in-the-loop. Advances in capabilities for creating synthetic environments are coordinated through STRICOM.

Figure VI-7. Ion Implantation Facility

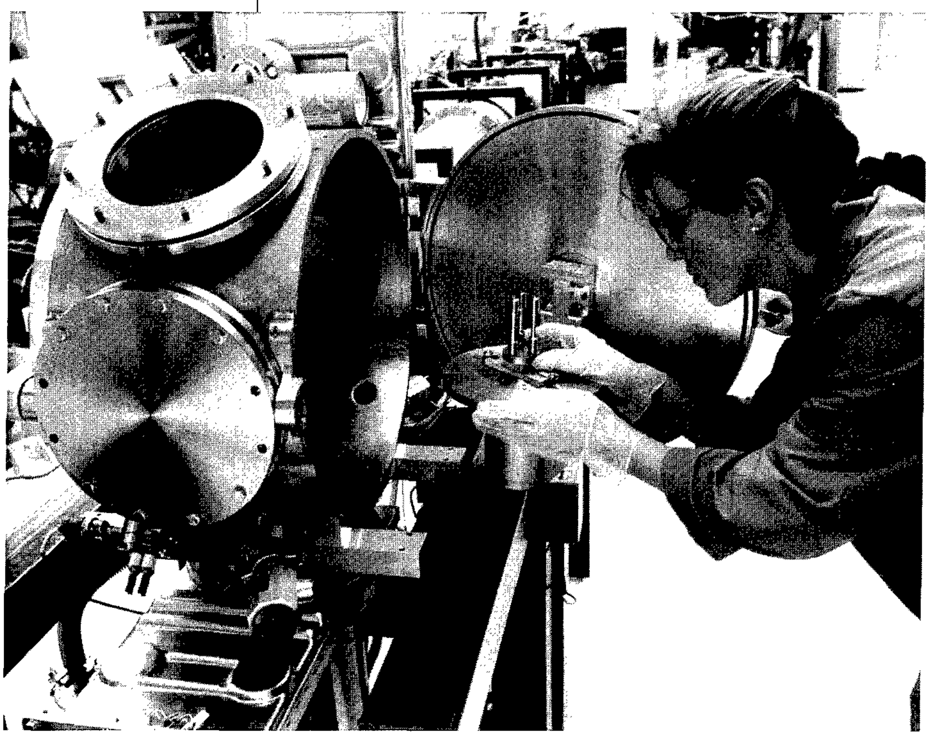
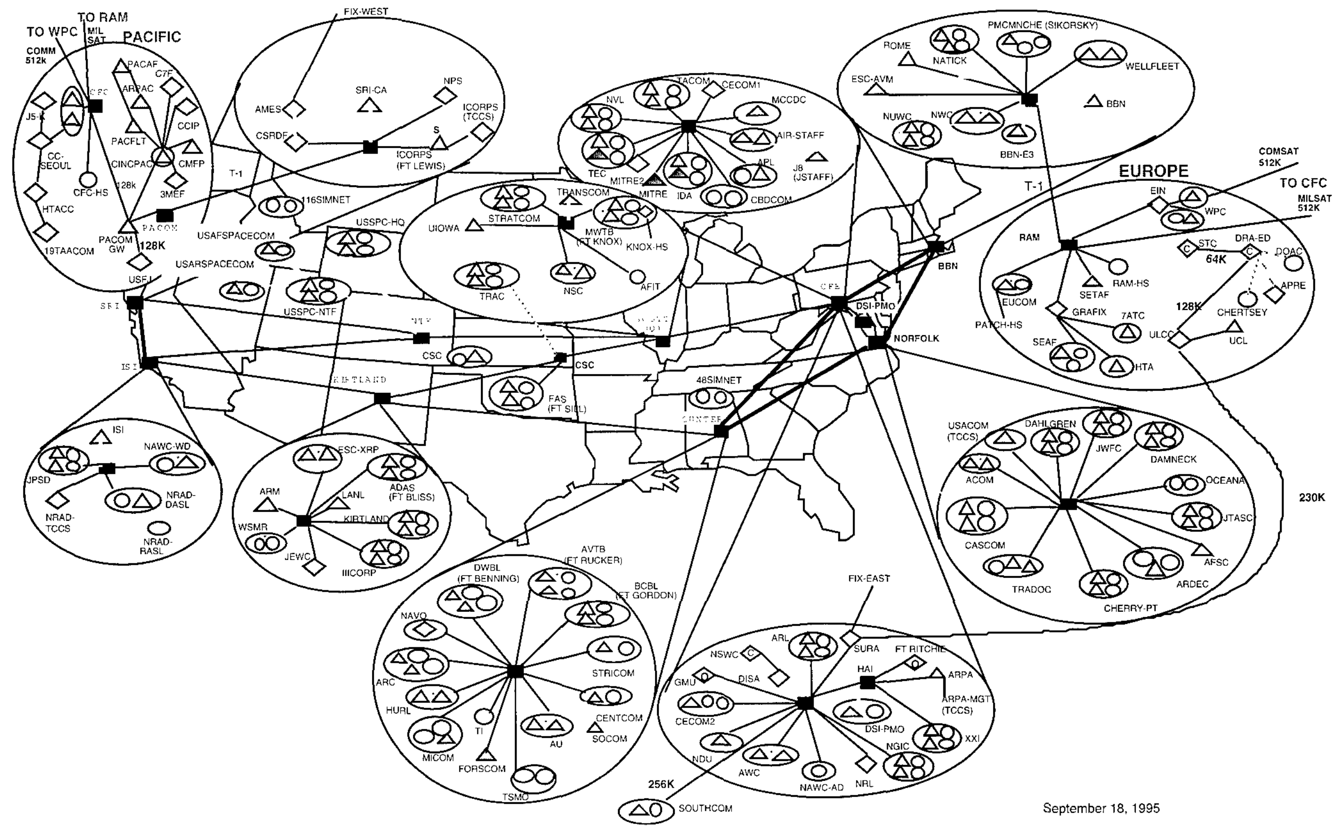


Figure VI-8. Defense Simulation Internet as of 9/18/95



Seamless synthetic environments are being achieved through the integration of simulation and modeling techniques, technology, capabilities, and processes. While the simulation factory will address lower level, more detailed representations of technology and designs important to system development, battle simulations will deal with the higher level of full battlefield representations important to the development of combined arms warfighting capabilities.

Through the design and analysis of concepts in controlled synthetic environments, distributed interactive simulation offers increased savings in time and money by reducing the need for expensive mock-ups and field testing. Synthetic environments enhance the possibility for exploring various design options in full battlefield context, allowing workers to design and assess concepts that could not be explored using traditional approaches because of safety, environmental, and cost considerations. Distributed interactive simulation can thus be used Army-wide to accelerate research and to permit advances in technology to be brought to the field in a timely fashion, helping to assure technological superiority on the battlefield.

a. Three Integral Components

The Defense Science Board (DSB) Task Force on Simulation, Readiness, and Prototyping defines simulation as "everything except combat" with three integral components—live [operations with real equipment in the field]; constructive [war games, models, analytical tools]; and virtual [systems and troops in simulators fighting on synthetic battlefields]. While the first two components are technically mature, the virtual component is now evolving. Virtual capability is improving through technology advances in high-performance computing (HPC), communication, artificial intelligence (AI), and synthetic environment realization.

The Army has adopted an electronic battlefield (EBF) which was put forth by the Army Science Board 1991 Study on Army Simulation Strategy. The long-term objective of the EBF concept is to develop and implement a single, comprehensive environment for operational and technical simulation. The EBF is designed to support combat development, system acquisition, test and evaluation (T&E), operational test and evaluation (OT&E), training, mission planning, and rehearsal in Army specific and joint operations (see Figure VI-9).

b. Approach

The near-term priority is to establish an Advanced Distributed Simulation (ADS) infrastructure to improve training and force readiness. The ADS infrastructure includes the following:

- High-performance computing.
- Real-time, large-scale networking.
- Data and application software methodologies for interoperability, scalability, and realism.
- Multilevel secure, hierarchical, open architecture standards, interfaces, and products.

To implement this concept and investment, the Army established several new initiatives. They are: the TRADOC Battle Laboratories; the Distributed Interactive Simulation General Officer Steering Committee (DIS GOSC) recently subsumed by the newly established Army Model and Simulation General Officer Steering Committee (AMSGOSC) and its collateral organizations; STRICOM; FORCE XXI; and the Information Sciences and Technology Directorate (ISTD) within ARL.

TRADOC is the Army's DIS functional manager. As such, TRADOC is responsible for the Army-wide integration of DIS requirements, the development of the DIS Master Plan, proponency for DIS verification and validation, and prioritization of the scheduling of DIS facilities.

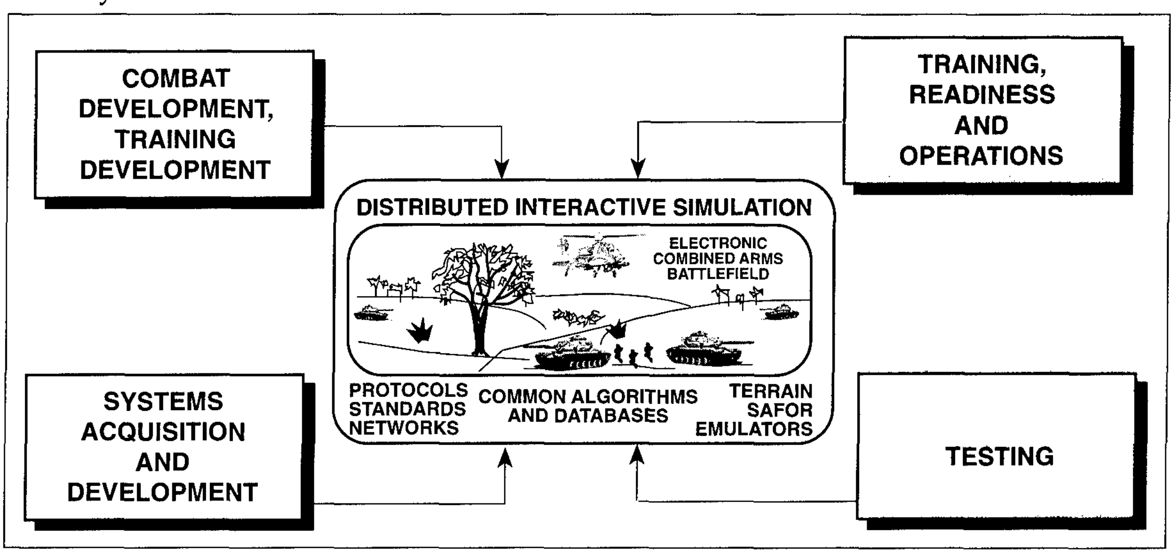
STRICOM is the Army's technical agent for DIS technology development and network management. STRICOM activities include the research, development, procurement, and support of simulators, simulations, and training devices, as well as the DoD lead responsibility for DIS-related standards and protocols and for coordination with industry.

Army XXI, the Army of the 21st Century, will be thoroughly evaluated using DIS technology to test concepts, doctrine, and the impact of proposed equipment and their contribution to warfighting.

The ARL ISTD was formed to put the major battlefield information sciences and technologies under one organizational umbrella to focus its work on the Army's operational information needs for Force XXI and beyond. This includes all M&S activitivies in support of the electronic battlefield.

The Army established the AMSGOSC to oversee DIS and other M&S-related activities from a corporate perspective. It is co-chaired by the Vice Chief of Staff of the Army (VCSA) and the ASA(RDA), who also co-chair the Army Science and Technology Advisory Group (ASTAG). An expanded AMS Executive Committee (AMSEC), co-chaired by the DUSA(OR) and the DCSOPS, will provide

Figure VI-9. Synthetic Environment for Distributed Interactive Simulation



overall management and establish three working groups—the Advanced Simulations Working Group, the Requirements Generation Working Group, and the AMS Management Plan Working Group. The Working Groups are chaired by the Army Modeling and Simulation Office (AMSO), which is charged with developing an integrated investment strategy across the three domains encompassed by the electronic battlefield: (1) advanced concepts and requirements (ACR); (2) research, development, and acquisition (RDA); and (3) training, exercises, and military operations (TEMO) (see Figure VI-10). Each has a domain manager at HQDA level, and a domain agent at MACOM level (TRADOC for ACR and TEMO, AMC for RDA). Management Plans and investment plans will be prepared for each domain.

The DIS Master Plan describes the program currently in place, the envisioned future capabilities, and the plan to achieve these objectives. As a follow-on to the DARPA/Army SIMNET program, the Army established a two-pronged investment strategy for DIS to support Army training and acquisition (Figure VI-11). The two programs—the Combined Arms Tactical Trainer (CATT) and the Battlefield Distributed Simula-

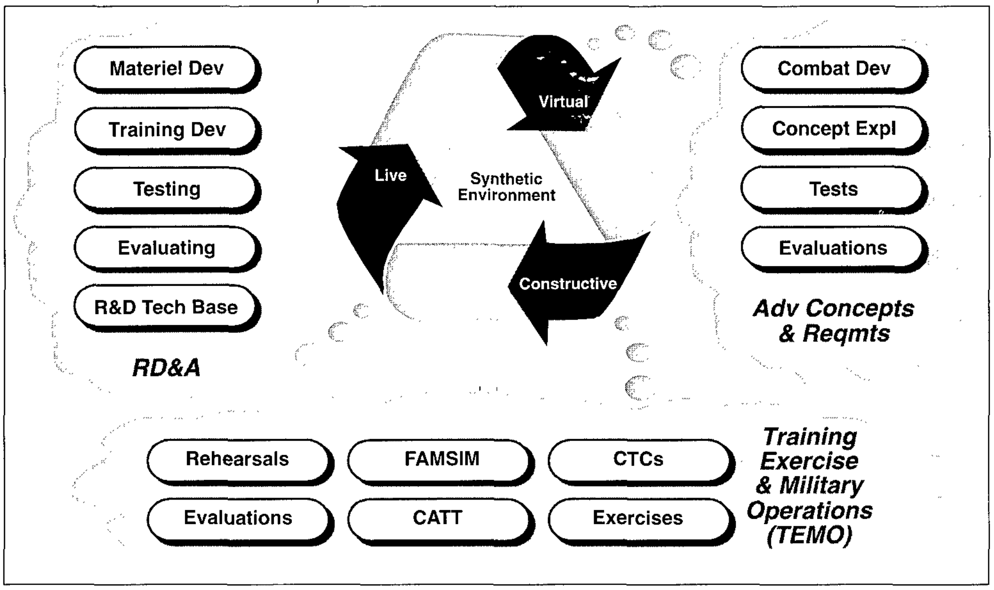


Figure VI-10. DIS Synthetic Environment. A time and space coherent representation of a battlefield environment measured in terms of human perception and behavior of those interacting in the environment.

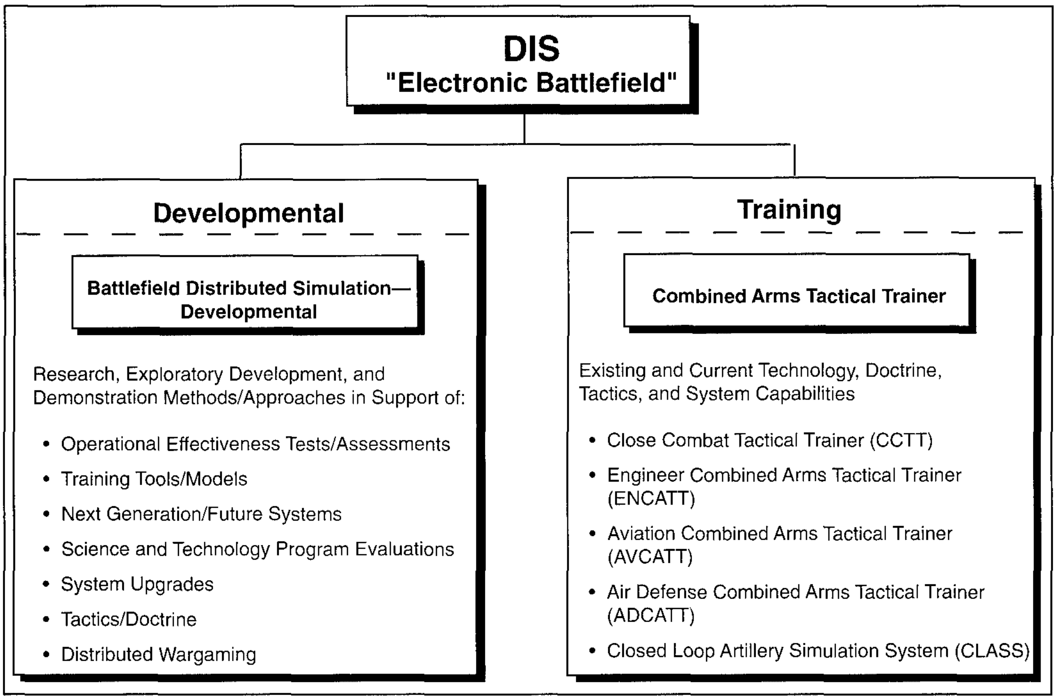


Figure VI-11. DIS Electronic Battlefield

tion-Developmental (BDS-D)—are directed to provide real-time, man-in-the-loop, synthetic environment simulation capabilities as follows:

- Link actual combat systems, war game simulations, and manned simulators into a hybrid real/virtual battlefield environment.
- Provide an open-ended hierarchical architecture with DoD common standards and protocols.
- Provide a realistic behavioral representation of the battlefield at each echelon.
- Orchestrate a large-scale distributed networking of resources.

The CATT focuses on integrating existing systems, tactics, and doctrine into a combined arms training environment from vehicle crew through battalion task force. BDS-D is directed toward future systems and concepts and encompasses all phases of materiel, combat and training developments, and testing.

The CATT program has identified requirements for five components: the Close Combat Tactical Trainer (CCTT) (see Figure VI-12), the Fire Support CATT, the Aviation CATT, the Air Defense CATT, and the Engineering CATT. Initial Operational Capability (IOC) for CCTT is planned for 1999, providing the baseline capability for development and integration of the other components. The CATT trainers will employ standard protocols, open architecture, and reusable simulation software. TRADOC proponent systems will be joined by a geographically distributed communication network to conduct combined arms training on the same synthetic battlefield.

The BDS-D Program is developing a distributed simulation capability linking government, university, and industry sites into an accredited, real-time, warfighter-in-the-loop simulation of the joint and combined battlefield. Manned simulators on the network embody the operational characteristics of the systems they represent. Semi-Automated Forces (SAFOR), with a man-in-the-loop, simulates the presence and actions of groups of one or more systems in a virtual battlefield environment. The BDS-D includes an evolutionary process and strategy to systematically develop, maintain, and use technologies, and associated hardware and software to achieve the long-term objective of an electronic battlefield (see Figure VI-13). This program continually exploits the advances forthcoming by our national ADS science and technology developments. The Army ADS S&T program is focused on technology development for the following:

- Army-specific requirements to ensure their timely availability to be placed in the BDS-D process and other simulation applications.
- The electronic battlefield of tomorrow, where advanced, interoperable, distributed simulations—live, constructive, virtual—at geographically separated locations are connected together to cooperatively form highly realistic synthetic environments. These environments encompass highly complex and dynamic problems of requirements definition and analysis, science and technology development, acquisition and prototyping, test and evaluation, production and logistics, training and readiness, and military operations. These factors can be addressed within

Figure VI-12. Close Combat Tactical Trainer (CCTT)

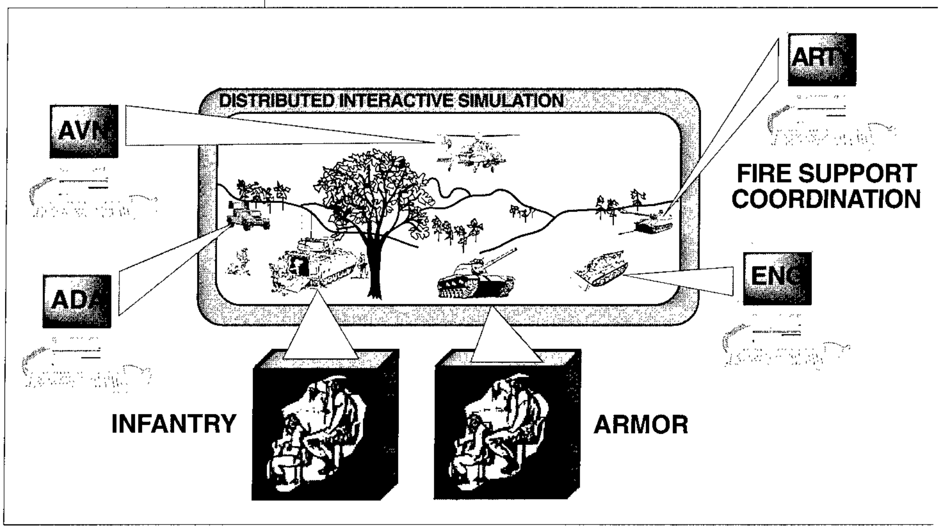
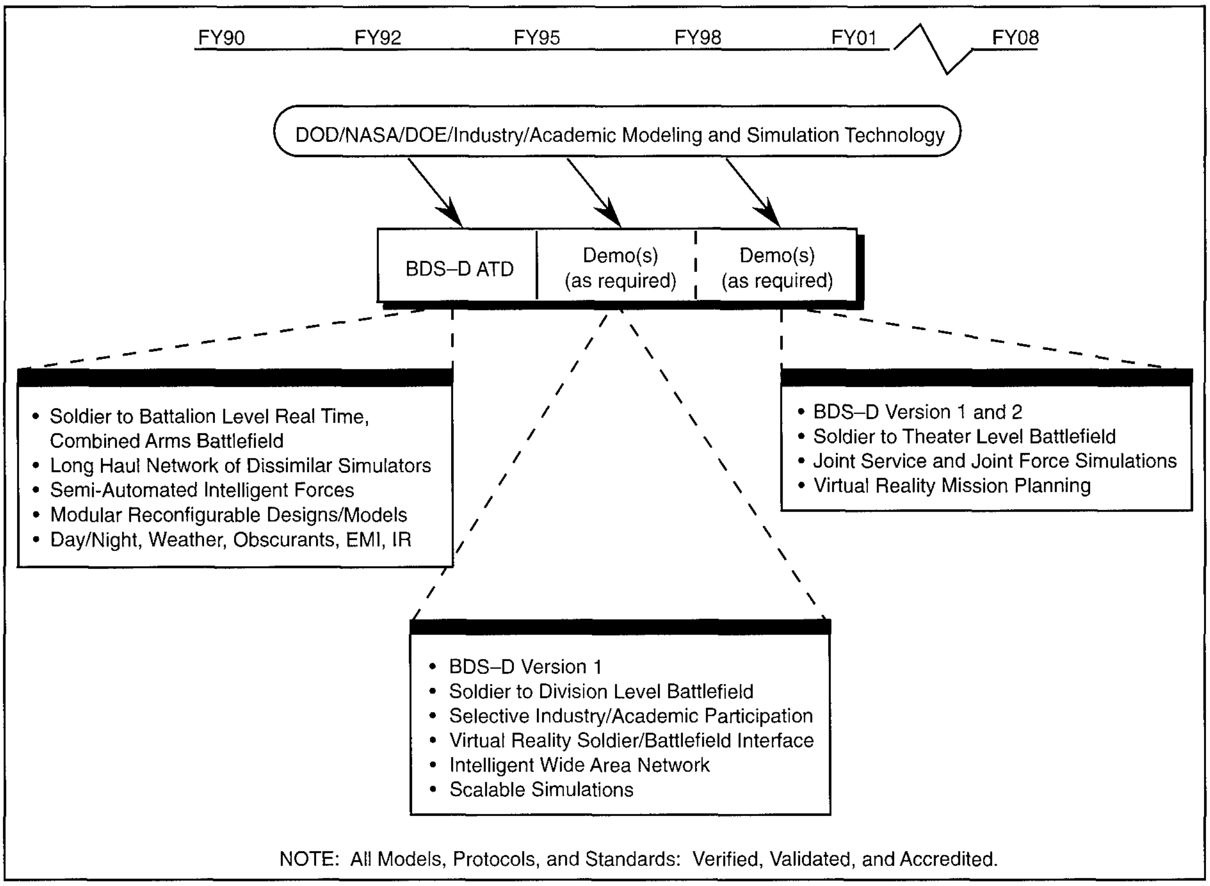


Figure VI-13. BDS-D Program



the full spectrum of scale and resolution in real time.

The planned Defense Simulation Internet (Figure VI-8, above) will be the connecting linkage which will make the DIS function and provide the high level connectivity necessary to accomplish R&D and training goals. This network is being expanded to take in the TRADOC Battle Labs, permitting testing of new doctrine and tactics in advance of actual field trials.

4. Modeling/Software/ Testbeds

Advances in computer technology have allowed Army engineers and scientists to make increasing use of models and simulations. Their use has resulted in substantial savings. One area where costs have been cut is contracting. When hardware procurement is eliminated because the needed information can be obtained through simulation, both time and money are saved. In addition, environmental impacts such as noise and pollutants generated during physical trial and error evaluation are eliminated. The following sections discuss (a) Computer Modeling and Simulation, (b) Software Technology, (c) Physical Simulation, (d) Hardware-in-the-Loop Simulation, (e) Combined Arms Battlefield Soldier-in-the-Loop Simulation, and (f) Test and Evaluation Simulation.

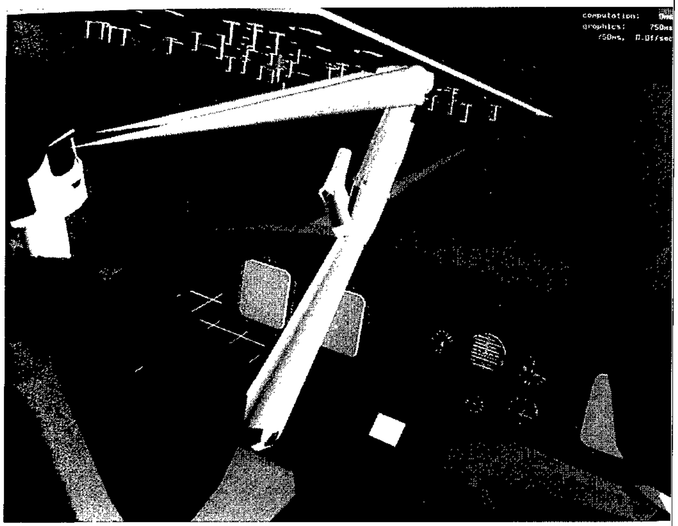
a. Computer Modeling and Simulation

Computer simulation and modeling can be used to evaluate experimental conditions and approaches and generate images of complex data. Visualization techniques used with complex modeling permit scientists and engineers to exploit new concepts without the development of costly prototypes and enable visual images to be developed without resorting to photographs or artists' concepts. Computer simulation and modeling is applicable to a wide range of technical disciplines as the following examples show.

Human factors modeling

An example of ongoing research is the development of a human performance model for simulating the interactions among operators, tasks, equipment, and their operating environments. The Army Research Laboratory Human Performance Model Program uses "JACK," a three-dimensional computer-aided design human figure model developed by the University of Pennsylvania (see Figure VI-14).

Figure VI-14. "JACK," a 3-D computer-aided design human figure model, is used to evaluate soldier interactions with weapon system design concepts.



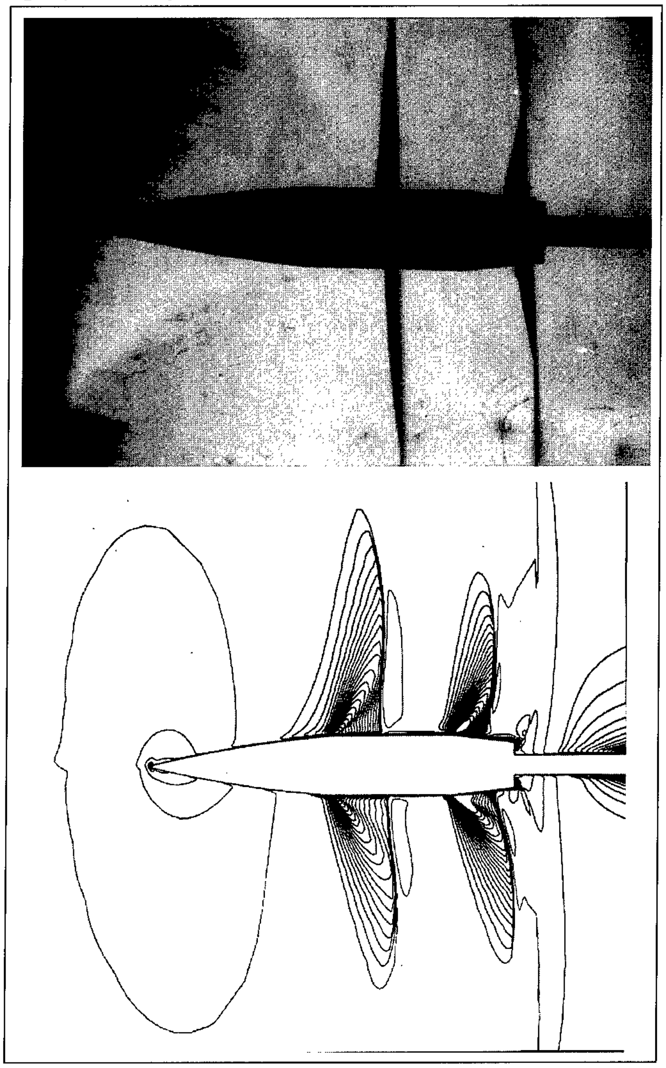
An example of the use of JACK is the Aviation RDEC's A31 (Army-NASA Aircrew/Aircraft Integration) Program, an exploratory effort aimed at producing software tools and methods to improve the human engineering design process for advanced technology crew stations. The program's basic approach is to embed models and principles of performance (e.g., vision, memory, decision making, and anthropometry) into a computer-aided design system. The resulting tool, called the Man-Machine Integration Design and Analysis System (MIDAS), supports "what if" analyses concerning the entire range of human engineering design concerns. Through MIDAS, a computer simulation is produced in which human performance models attempt to accomplish their prescribed tasks within a user-specified mission context and cockpit configuration. This approach allows variations of mission procedures and cockpit equipment to be explored rapidly, prior to committing a design to an expensive hardware simulator where more detailed human-in-the-loop analyses are performed.

Armor and projectile modeling

High-speed supercomputers with large memories have greatly enhanced our capabilities in modeling new armor concepts and advanced projectile technology.

Recent large-scale simulations have provided insight into the potential benefits of advanced high-velocity projectiles. Figure VI-15 illustrates one penetrator concept. The penetrator is composed of a train of segments supported in a carrier tube. The train-of-segments model is a laboratory version of a segmented projectile that may have merit for use in future armor systems.

Figure VI-15. Computer simulations of device design and operation can be used instead of costly prototyping and field tests. The comparison shows the accuracy with which computer simulations can reflect the physical world. *Top:* experimental projectile flight; *bottom:* simulated projectile flight.



Environmental modeling

Army tactical operations must take into account the environment in which they take place. Terrain information provided in digital form and atmospheric information about the planetary boundary layer which provides an understanding of the dynamics of wind, relative humidity, temperature, and turbulence fields over complex terrain are employed in wargames and simulations to determine the outcome of tactics changes and new equipment introductions. Climate data bases provide realism by projecting different weather conditions into a simulated theater of operations. Weapon systems are evaluated for effectiveness, taking into consideration target detection probabilities based on climate and terrain masking.

Weapons and fire control modeling

The Armament Research, Development, and Engineering Center (ARDEC) at Picatinny Arsenal, New Jersey, has established a DIS Node for the purpose of determining and presenting how technology, weapons, and weapons mixes can be used to maximize the effectiveness of the soldier. A "core" capability exists which is sufficiently flexible to support varied simulation requirements. Further, ARDEC is in the process of developing system upgrades to add capability for engineering level analysis. The purpose is to simulate before bending metal.

b. Software Technology

DARPA is the sponsor of the Software Technology for Adaptable, Reliable Systems (STARS) Program, whose goal is to increase software productivity, reliability, and quality through the adoption of a new software engineering paradigm called megaprogramming. Megaprogramming is based on modern software development processes and the domain-specific software architecture and reuse concepts integrated with state-of-the-art software engineering environment.

As part of the STARS strategy to accelerate the shift within the DoD to the megaprogramming paradigm, STARS is sponsoring megaprogramming demonstration projects on actual DoD systems within each of the Services. These demonstration projects will help quantify the benefits of the megaprogramming paradigm and the issues involved in transitioning to this new paradigm.

In conjunction with the Army's STARS demonstration project, CERDEC has developed the STARS Laboratory. This laboratory provides support for the development of domain models, domain architectures, and reusable assets. The software engineering environment is also used to reengineer C4I weapon system software to include the integration of domain architectures and assets in the application software.

At the completion of the STARS projects, CECOM will have a modern, state-of-the-art software support environment that sustains the megaprogramming concepts and is tailorable to various domains and projects. The integrated tool set and processes will significantly reduce cost and improve the productivity and quality of future software-intensive Army projects.

c. Physical Simulation

Laboratory physical simulations are used today in Army research to emulate real-time physical motions of active systems in the field. In many situations, computer-generated models and simulation systems can interact with physical simulations to greatly reduce the need for costly and time-consuming field tests of prototypes.

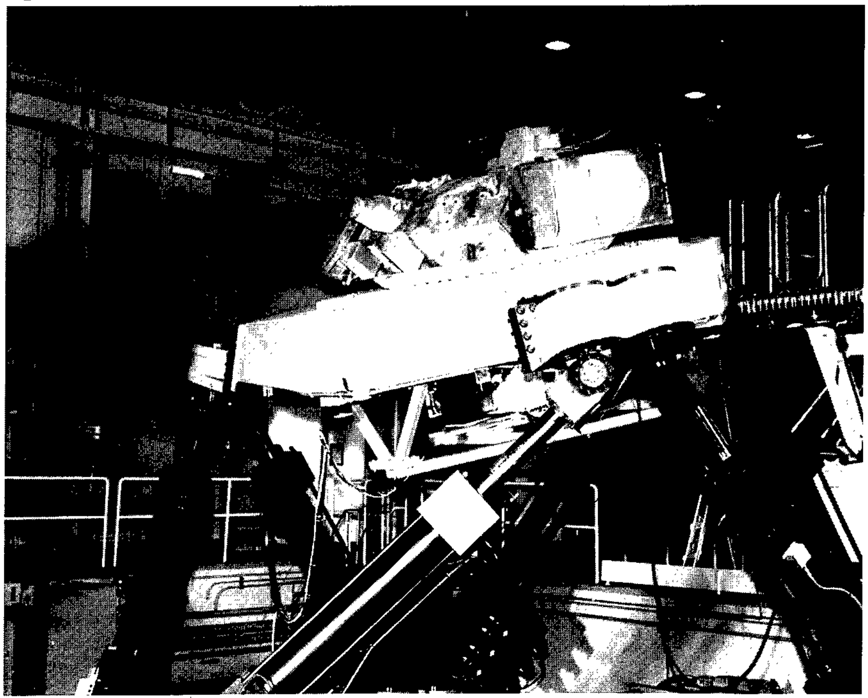
Following are examples of advanced physical simulation facilities operated with computer-generated models and/or simulation systems.

The Crew Station/Turret Motion Base Simulator (CS/TMBS) is a full six degrees of freedom laboratory simulator which has uniquely high performance capabilities. It can impart a maximum of 6g acceleration to a heavy combat vehicle turret weighing up to 25 tons and replicate, via computer control, actual motions/vibrations that would be encountered while traveling over rough cross-country terrain represented in the computerized databank.

This simulator, located at TARDEC, is man-rated and approved for occupancy by a crew. The CS/TMBS plays an important role in turret system development, characterization, and virtual prototyping activities in a variety of combat vehicle programs.

Several series of laboratory tests have already been completed using this simulator, including the testing of an experimental turret designed and built by the General Dynamics Company and the operation of different azimuth drive motors in a Bradley Fighting Vehicle Turret (see Figure VI-16).

Figure VI-16. The Crew/Station/Turret Motion Base Simulator (CS/TMBS) allows new vehicle turret designs to experience real-world operational environments in a controlled laboratory setting.

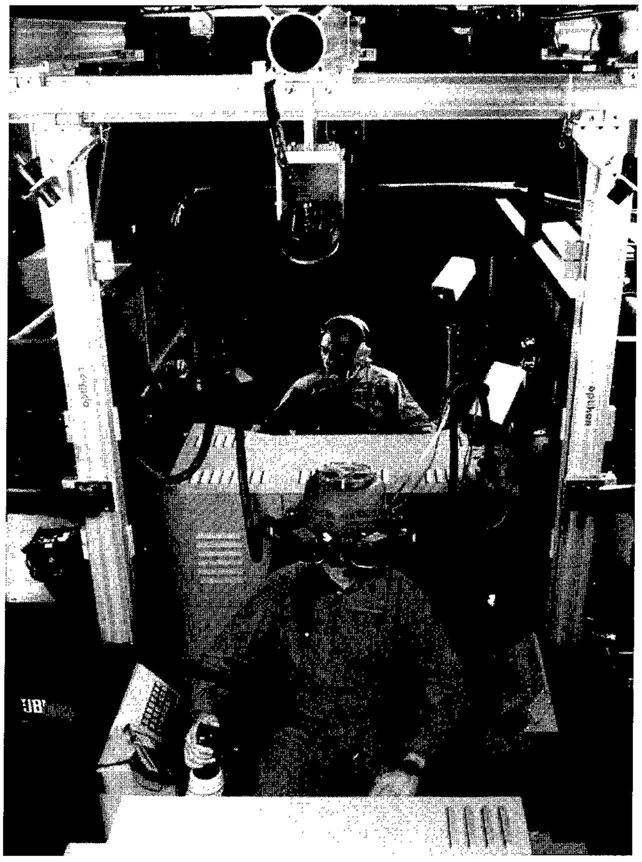


There are several significant advantages of being able to conduct man-in-the-loop tests in the laboratory. Foremost of these is close control of the influential parameters and exact repeatability of tests for comparing the effect of different components.

TARDEC has received and is installing an exciting propulsion test capability called Power and Inertia Simulator (PASI). This advanced dynamometer system uses mathematical expression to cause this electric motor-generator dynamometer system to replicate dynamic conditions such as national/tanslational inertia, wind, and slope. On the PASI, true operational profiles can be simulated.

The Aviation RDEC Crew-Station Research and Development Facility (CSRDF) supports the evaluation of new concepts for human-system interactions for advanced rotorcraft. Effects of malfunctions, automation alternatives, and mission equipment tradeoffs can be conducted in this synthetic environment of 3-D visuals, sounds, and tactile stimuli (Figure VI-17). The degree of realism achieved in such systems can best be appreciated by seeing a pilot emerge from a laboratory "flight" showing perspiration and other signs of stress. The CSRDF will be used extensively to support the Rotorcraft Pilot's Associate Advanced Technology Demonstration and is one of the primary simulators used to validate DIS protocols and the BDS-D program. The Aviation Test Bed at Fort Rucker and the CSRDF have already been linked to support FORCE XXI objectives. This linkage is being extended to include TACOM, LOSAT, and the Sikorsky Comanche Simulators.

Figure VI-17. Innovative rotorcraft technologies are evaluated for operational compatibility in the rotorcraft simulator facility.



Another example is the Simulator Training Advanced Test Bed for Aviation (STRATA). Through a cooperative agreement with the Government of Canada, the Army Research Institute (ARI) for the Behavioral and Social

Sciences developed the STRATA research simulator to examine the full range of training device and flight simulator training strategies and tradeoffs and design requirements for future low-cost simulators. STRATA is a dedicated research facility at ARI's Fort Rucker, Alabama, field unit for aviation training research. The modular design of STRATA permits rapid reconfiguration to emulate training devices with different visual displays, cockpit configurations, aerodynamic models, tactical threat sophistication, motion cueing, and visual data base detail. The use of STRATA will enable the Army to empirically determine the most effective training strategies using an affordable mix of live exercises and existing training aids, devices, simulations, and simulators for initial flight skills for individuals through unit combat tasks.

The Construction Engineering Research Laboratory (CERL) of the Corps of Engineers operates a Heating, Ventilating, and Air Conditioning Facility (HVAC) to provide a place to study and experiment with building environmental control systems. The Facility was constructed with a grant from the Department of Energy and has seven distinct sections: (1) ventilation, (2) hot water supply loops, (3) chilled water supply loops, (4) four zones, (5) HVAC system configuration, (6) facility controls, and (7) data acquisition. The test facility is used on a continuing basis to aid in the improvement of HVAC systems and controls used in military buildings in the quest for reduction in the cost of facility operation.

CECOM's Night Vision and Electronic Sensors Directorate Survivability Integration Laboratory has developed a facility to support the development and testing of integrated aircraft and ground vehicle sensors and countermeasures. The Multi-Spectral Environmental Generator and Chamber (MSEG&C) provides 360 degree radar frequency, laser, infrared, and ultra-violet simulation of air defense radars, surface-to-air missiles (SAMs), top attack/smart munitions, and laser threats. Various individual and integrated protection equipment is used to simulate ground vehicle and aircraft attitudes as the vehicle is artificially moved through the threat environment. The equipment is instrumented and placed on a computer-controlled table in the center of an anechoic chamber (Figure VI-18). New threat simulators are being added to support the Hit

Figure VI-18. Multispectral Environmental Generator and Chamber

Avoidance ATD, distributed interactive simulation with Fort Rucker and Fort Knox, the Rotorcraft Pilot's Associate ATD, and PEO customers.

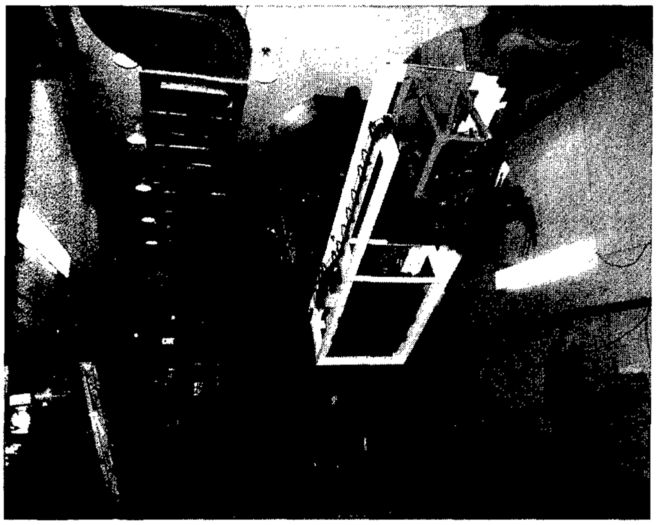
CECOM's Space and Terrestrial Communications Directorate has a facility to incorporate the realistic effects of C3I/EW models. The S&T Modeling and Simulation facility houses a large assortment of network models and tools to develop, run, and analyze complex simulations; to obtain information on network/system throughput traffic distribution; delays/response times; and overall performance. Two distributed interactive simulation network terminals are being added, which will be interconnected to other DIS facilities via Army Interoperability network circuits.

d. Hardware-in-the-Loop Simulation

Hardware-in-the-loop simulation, which tests various types of systems using a combination of actual hardware and computer simulations, provides a significant return on investment for the Army.

One example of hardware-in-the-loop simulation is ARDEC's Ware Simulation Center located at Rock Island Arsenal, Illinois (Figure VI-19). This physical simulator is used to provide a realistic emulation of the field environment that the armament system will encounter. The facility can test weapons using up to 30mm live or 40mm inert ammunition. In addition, the facility's six degrees of freedom

Figure VI-19. The Ware Simulation Center's Six-DOF mount allows conceptual and fielded weapons to be fired in realistic mounting environments to isolate design deficiencies in controlled laboratory conditions.



simulator is a large mount capable of holding weapons, gun turrets, and vehicle sections weighing up to 10,000 pounds and measuring up to 8.1 feet high. Programmed vibrations as well as pitch and yaw motions may be applied to the attached loads while its weapons are test fired in the indoor range. The combination of a large motion simulator situated in an indoor firing range provides a unique opportunity to test armament systems under controlled conditions.

Another example of hardware-in-the-loop simulation is the AMCOM Open-Loop Tracking Complex (OLTC), a computer-automated electro-optical countermeasure (EOCM) simulation facility that provides electronic warfare analysts the tools for evaluating the performance and effectiveness of electro-optical air defense missile systems and guidance assembly hardware in the presence of countermeasures. The facility allows for the performance verification of a missile guidance assembly before firing, permits the verification of missile performance under countermeasure environments in preparation for live-fire programs, and permits the discovery of missile system weaknesses throughout the development and acquisition phase of the missile.

These types of systems provide the highest level of simulation sophistication available, permitting hundreds of simulated "flights" to be made safely, at a cost significantly less than the cost of a single flight test. Simulated flights can be exercised in a secure environment to explore system vulnerabilities and capabilities against threats and countermeasures that do not lend themselves to free space testing.

CECOM has implemented the Army Interoperability Network (AIN), a nationwide suite of distributed communications capabilities and services to support interoperability and software development for Army C4I systems throughout their life cycle. The AIN provides the Army infrastructure for C4I systems to achieve the objectives of the Army Enterprise Strategy, i.e., Battlefield Digitization and C4I for the Warrior. The AIN provides rapid engineering support solutions that replicate battlefield configurations by networking dispersed fielded C4I systems. Current AIN major operational equipment now includes the AIN Central Control Facility; Protocol Assessment Facility; four sites at Fort Monmouth; and remote sites at Fort Leavenworth, Fort Sill, and Fort Huachuca. A remote site is planned for PEO Armored Systems Modernization at General Dynamics Land Systems, Warren, Michigan. A transportable AIN node is available to provide a quick-reaction AIN access in situations requiring rapid test support. The AIN is the Army's infrastructure for linking the Battle Labs with the RDECs.

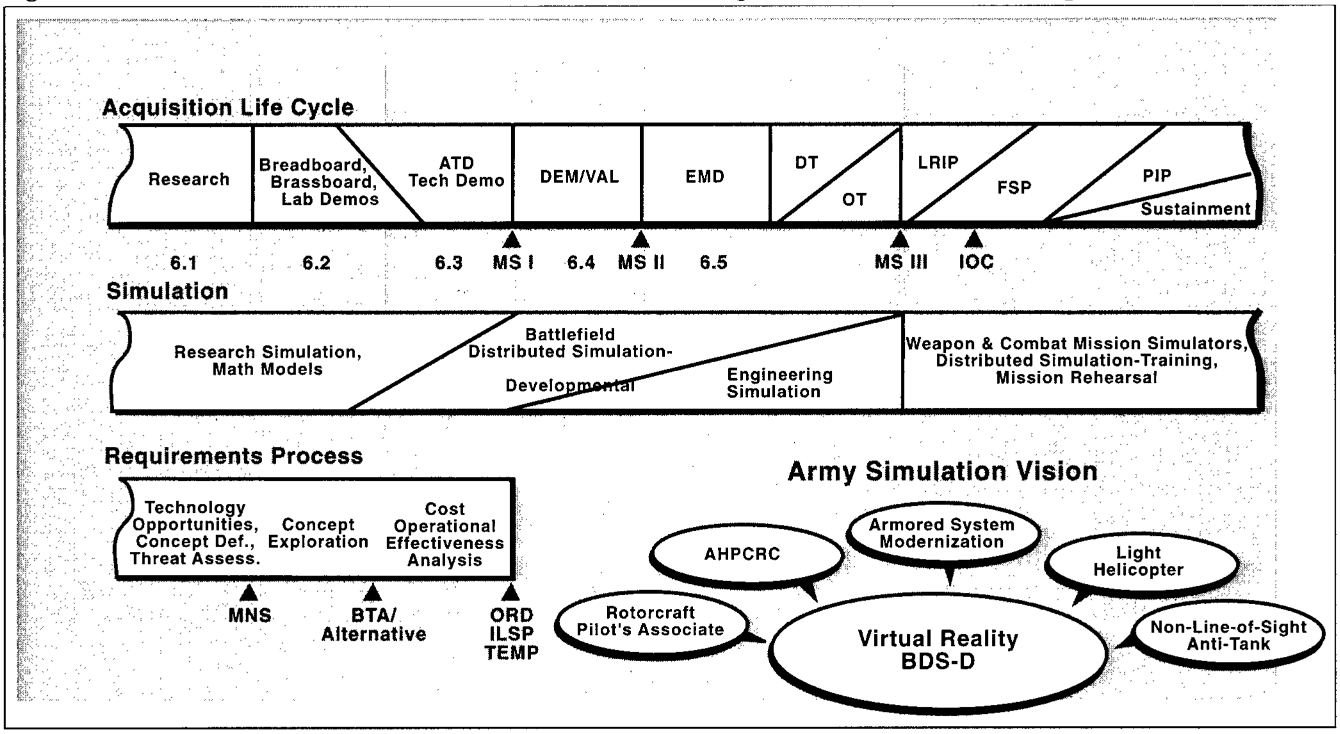
e. Combined Arms Battlefield Soldier-in-the-Loop Simulation

Enhanced design architectures and improved battlefield simulation techniques are rapidly growing areas of Army simulation and modeling capability. The Army leadership has a vision of how the totality of battlefield simulation technology and techniques can be used throughout the research and acquisition process (see Figure VI-20).

The cornerstone of the Army vision is the BDS-D program, a long-term project with the ultimate objective of creating and maintaining a distributed, state-of-the-art network capability linking government, university, and industry sites into a simulation of the combined and joint arms battlefield. The BDS-D program is delineated in Figure VI-11 and the surrounding text.

This distributed interactive simulation capability builds on the continued growth and development of the DARPA-sponsored SIMNET technology, currently the basis for Army

Figure VI-20. Potential Use of Battlefield Simulations Throughout the Research and Acquisition Process



simulation test bed facilities at Fort Knox, Kentucky; Fort Benning, Georgia; and Fort Rucker, Alabama. The BDS-D supports materiel development, combat development, training development, and operational testing by providing a low-cost, effective alternative to proof-of-principle demonstrations, field tests, and operational evaluations in all phases of force development. The program approach will achieve seamless simulation of systems, including simulations for command and control, simulators for weapon systems/platforms, actual operational systems, and semi-automated forces. An open system design architecture, with a common set of protocols and standards to achieve interoperability of simulators, is the keystone of the BDS-D program development.

Use of the object-oriented design approach for networking crewed simulators and SAFOR provides a multidimensional simulation of the battlefield environment that allows insertion of the warfighter into the loop at all phases of force development and training. The simulated warfighting environment can be packaged or scaled to address a variety of uses, so that smaller segments of simulation can be included in larger synchronized environments when required. This will be achieved through a system of local area networks (LANs) of low-cost battlefield simulators, experimental and high-fidelity remote nodes, and SAFOR, all linked together via a system of long-haul networks. This system will provide a virtual combined arms and joint combat operations environment for materiel and combat development and for operational testing exercises.

Through the use of current and emerging long-haul data communication capabilities to create wide-area networks, simulation capabilities will be resident at geographically separate sites and linked together to form much larger synchronized simulation environments. This characteristic allows the simulation environment to be "packaged" in sizes and places corresponding to the size and location of actual units for evaluating weapon system, force development, and training concepts (see Figures VI-21 and VI-22).

Armored Systems Modernization (ASM) is similarly being analyzed under the BDS-D concept. ASM mobility, weapon station stability, and ride quality, as well as the survivability of all the ASM variants, will be evaluated in a true combined arms simulation. Anticipated ASM capabilities like the Vehicle Integrated Defense System (VIDS) and Combat Vehicle Command and Control (CVCC) are being simulated and evaluated via the BDS-D test bed resources;

Figure VI-21. With BDS-D, wargame exercise referees can observe training operations from any vantage point on the battlefield while remaining completely transparent to the players.

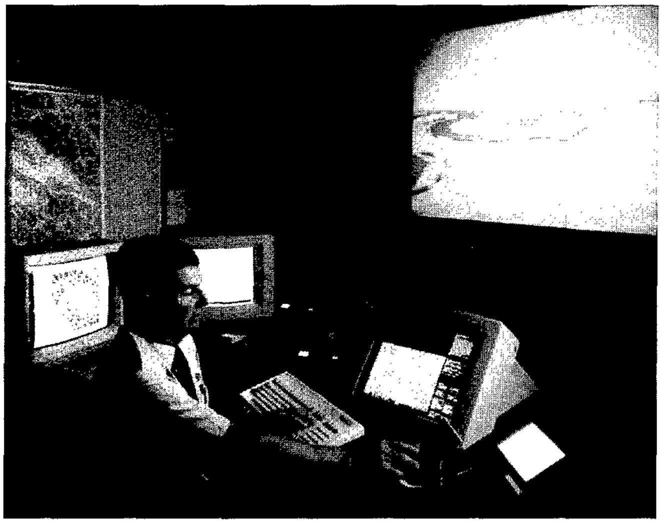
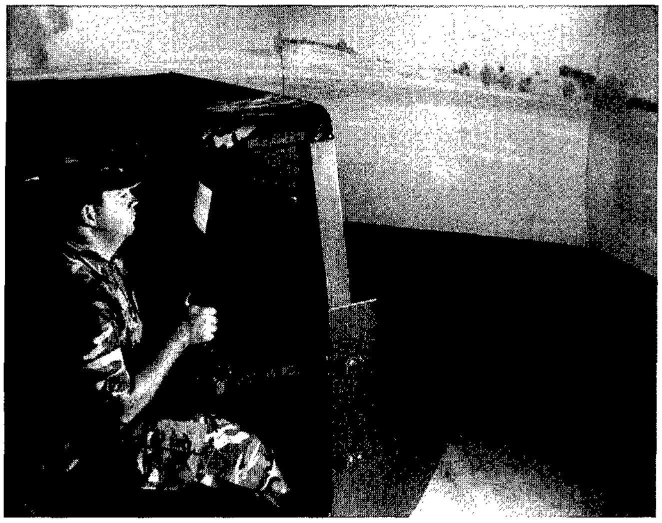


Figure VI-22. BDS-D will give weapon system operators the ability to more realistically train with non-line-of-sight missile technologies.



crew controls and displays for the Line-of-Sight-Anti-Tank (LOSAT) variant of the ASM family have been "prototyped" within the BDS-D resources and successfully used to describe valuable human factors modifications to be pursued by the weapon system program office.

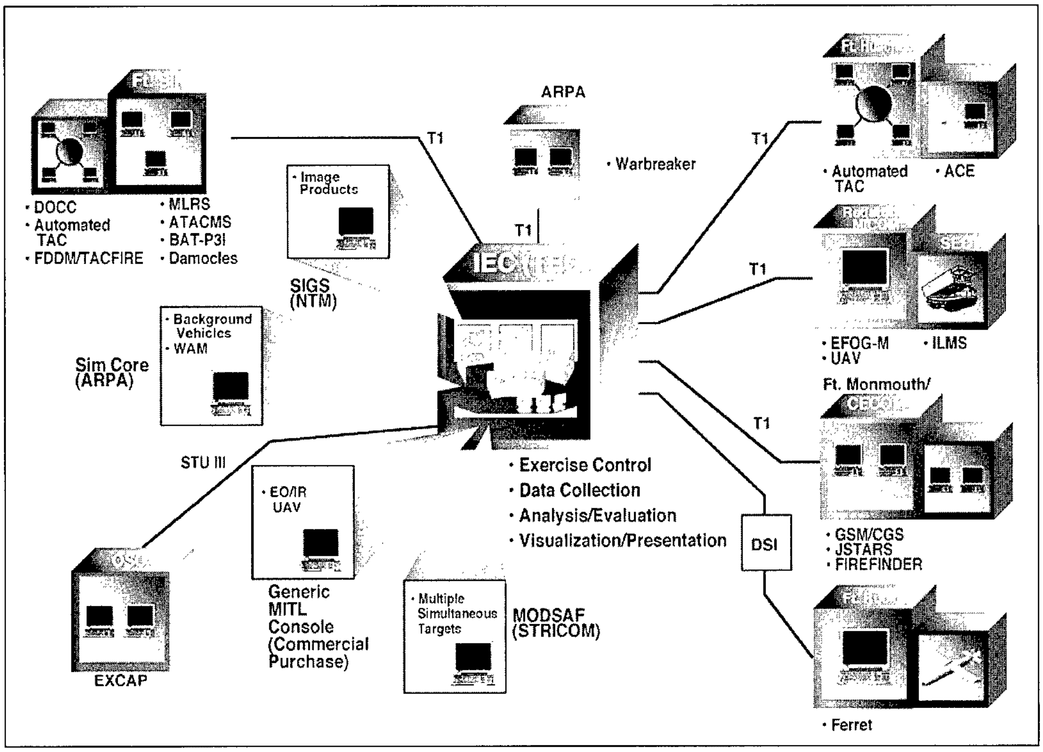
The Joint Precision Strike Demonstration (JPSD) is using DIS and wideband networking as a central experimentation and analysis element of the Precision/Rapid Counter Multiple Rocket Launcher (MRL) ACTD. The objective of JPSD is to demonstrate an Army all-weather, day/night sensor-to-shooter capability to locate, identify, and eliminate high-value, short-dwell targets and assess damage within tactically meaningful timelines. The specific objectives of the ACTD are to demonstrate the use of current and emerging technologies to rapidly defeat a MRL attack against South Korea and to provide leave-behinds that enhance the CINC's warfighting capabilities. Through use of DIS, JPSD has developed a distributed network, controlled by the JPSD IEC (see Figure VI-23), that combines live and simulated events into a real-time, virtual representation of the warfighting scenario. JPSD has used this capability to integrate a live ATACMS missile firing, live sensors (UAV and an advanced sensor), software simulations of precision munitions and targets, and manned intelligence and fire support C2 nodes to demonstrate the end-to-end timeline for acquiring, targeting, attacking, and assessing damage to a variety of target classes. FY95-96 efforts concentrated on in-depth experimentation for the MRL scenarios and on providing leave-behind capabilities.

The BDS-D will continue to expand, using additional modeling assets that either exist already or are under development. The goal by the year 2004 is to achieve seamless linkage of battle simulations, live field simulations of tactical engagements, and networked simulators using the object-oriented network design approach.

f. Test and Evaluation Simulation

Technological progress must be complemented by test and instrumentation facilities, including test and evaluation simulation, that can measure the technological progress being achieved. Environmental and safety concerns increasingly impose constraints on test and evaluation facilities. Maximizing simulation will minimize these environmental and safety issues. The full-scale testing of new weapon systems is both costly and time consuming. The ability to simulate the physical conditions of the battlefield for test and evaluation reduces the time to obtain data and cost. Bringing the test environment under laboratory control provides high quality,

Figure VI-23. Full Up DIS Simulation



reproducible data that can be recorded and analyzed during the test process.

The Battlefield Distributed Simulation-Developmental (BDS-D) program (see Section d, above) will ultimately be used to support test and evaluation.

5. Information Technology/ Communications

In order to speed information transfer within the S&T community, substantial improvements have been made in the supporting communications infrastructure.

- The explosive growth of microcomputers, software applications, and networking has created a watershed of opportunity to use information more effectively in the management of S&T within the community. Bulletin boards, LANs, and Wide Area Networks (WANs) are changing the way business is conducted, providing the opportunity for a major management initiative within the Army. Reengineering of workflows will occur as information is shared concurrently among organizations such that products are speedily delivered with higher quality.

6. Personnel

Approximately 22,000 in-house personnel support the Army R&D mission. Working with a diversified set of physical resources which range from solid-state physics laboratories to outdoor experimental ranges, these personnel conduct research, technology, and product support activities for the total Army in medicine, the life sciences, psychology, physics, engineering, and numerous other fields of science. Microelectronics, fludics, and digital computing are only three major examples of technologies in which major advances have sprung from our in-house organizations.

In order to enhance management of the acquisition fruits of the S&T process, an Army Acquisition Corps has been established, composed of career professionals who are dedicated to bringing a career commitment to the highly technical acquisition process. Persons committed to this specialized career field are offered significant educational opportunities to enhance their professionalism.

Demographic projections for college graduates indicate a declining number of engineers and scientists in the period from 1990 to 2015. To address this issue, which has received national attention, the Army is developing a comprehensive set of policies and plans to recruit, train, and retain scientists and engineers. These policies include the selective use of demonstration programs to enhance recruitment, the proper use of long-term fellowships for graduate degrees, and the placement of individuals in laboratories for "hands-on" work assignments. Retention is a major issue since technical personnel often are wooed with higher salaries by U.S. industry and academia. The experimental use of wider pay bands, special pay, and other OSD and Army initiatives are being studied to remedy this problem. For example, the Army has extended the career track for world-class scientists through the implementation of the Scientific/Technical (ST) Corps—equivalent to GS-16 through GS-18 in pay. In the past two years the total number of ST positions has risen from 3 to 40.

D. Summary

As illustrated in this chapter, the Army is exercising prudent investments in its supporting infrastructure to meet its objective of developing and maintaining world-class S&T capabilities to meet future Army needs. Simulation investments discussed in previous editions of this Plan are emerging at just the right time to support the needs of planners and operators faced with a base-deployed, downsized Army. This investment is meeting the needs of the TRADOC Battle Labs for planning the Army of the future and providing the materiel developers with the tools to demonstrate new technologies and operating capabilities in a more cost-effective way than has heretofore been available.

The Army will continue to use leveraging strategies wherever possible to interface effectively with other governmental bodies to effect the best solution to satisfying technological needs. We are exercising prudent investments of resources to ensure that it remains fully capable of meeting the needs of the Army.

CHAPTER VII

Technology Transfer

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CHAPTER VII

Technology Transfer

Domestic Technology Transfer and Dual Use Technology are integral elements of the Department's pursuit of its national security mission. They must be recognized as key activities of the DoD Laboratories. ... In line with the Department's new acquisition strategy, it is anticipated that steadily increasing percentages of RDT&E and other acquisition investments will ... involve dual use technology development and spin-off and spin-on of technologies.

Secretary of Defense William Perry

Our strategy is to place greater reliance on the commercial sector to reduce costs, shorten acquisition cycle times, and obtain technologically advanced defense equipment. The dual use programs ... are instrumental to the Department's goal of moving away from separate defense and commercial bases to an integrated, national industrial base.

Under Secretary of Defense Paul Kaminski

A. Army Technology Transfer—An Overview

The Army technology transfer program works in synergy with our national industrial infrastructure to strengthen both military and economic security. This military-commercial synergy has always been important, but as military resources decrease with the end of the Cold War and as commercial competition replaces military competition, it becomes more and more critical.

Whereas the Army once sustained a technology and production base that was focused on military needs and isolated by culture and rules from the civilian commercial world, we are no longer able to afford this luxury. In fact, in some technical areas ending this isolation will enable the Army to exploit commercial technology that is more advanced than its military counterpart.

But as we seek to meet our military needs from commercial sources, it becomes important to ensure that U.S. industry leads the world. Furthermore, the technology developed to meet military needs helps strengthen our international commercial competitiveness and contributes to economic security.

In the 1980s, formal technology transfer programs were initiated to apply "spin-off" from military technology to benefit the civilian economy and thus enhance national competitiveness. Within DoD, such programs were seen as, at best, necessary overhead functions. But with the decline of defense funding, changes in the nature of the military threat, and an increase in the rate of the change in commercial technology, DoD's emphasis has evolved to include "dual-use" and "spin-on" technology. The potential to bolster civil and military strength through a common production base is being recognized in DoD and in the larger national community. As cited in the quotations at the beginning of this chapter, technology transfer is now recognized as essential to DoD's mission. The Army Technology Transfer Program creates an environment that both fosters and facilitates the transfer of technology between military and civilian applications, thereby contributing to both our military needs and our economic competitiveness.

This chapter provides a description of the various components of the Army Technology Transfer Program. This program utilizes an exceptually wide range of different management approaches, legal mechanisms, and types of partners.

B. Dual Use Technology—National Defense and Economic Competitiveness

Economic strength and military strength are mutually supportive, and dual use technology can contribute to both. As defense spending declines, we must merge military and civilian technology and production bases wherever possible. Thus our military capability gains from the large investment in civilian R&D and production capacity, and, conversely, our economic capability gains from military investment (usually in leading-edge technology). Similarly, medical and environmental capabilities developed for the military have civilian application, and vice versa. Therefore significant effort is devoted to tailoring our R&D programs so we do not "reinvent the wheel" in areas where civilian capability leads, but effectively hand off our advances when they have value to the civilian economy.

This section highlights several programs which are especially designed to encourage development of dual-use capabilities, and to hand off those aspects of predominantly military capabilities (technologies, know-how, and facilities) that have civilian application.

1. Small Business Innovation Research (SBIR) Program

The SBIR Program allows the Army to access the innovative technologies of small, high-technology firms. Subject to the availability of SBIR funds, the Army supports small high-tech businesses in conducting high quality research, or research and development on innovative concepts. Of particular interest are R&D efforts leading to solutions of Army/Defense-related scientific or engineering problems while permitting the small businesses to commercialize their developed technologies in the private sector.

A government-wide effort mandated by Public Law, the SBIR program is intended to (1) stimulate technological innovation; (2) strengthen the role of small businesses in meeting federal R&D needs; (3) foster and encourage participation by minority, disadvantages, and women-owned small businesses in technological innovation; and (4) increase the commercial application of innovations derived from federal R&D. Firms participating in SBIR must be "small businesses" according to the Small Business Administration's definition (under 500 employees), and must be U.S.-based, for-profit businesses.

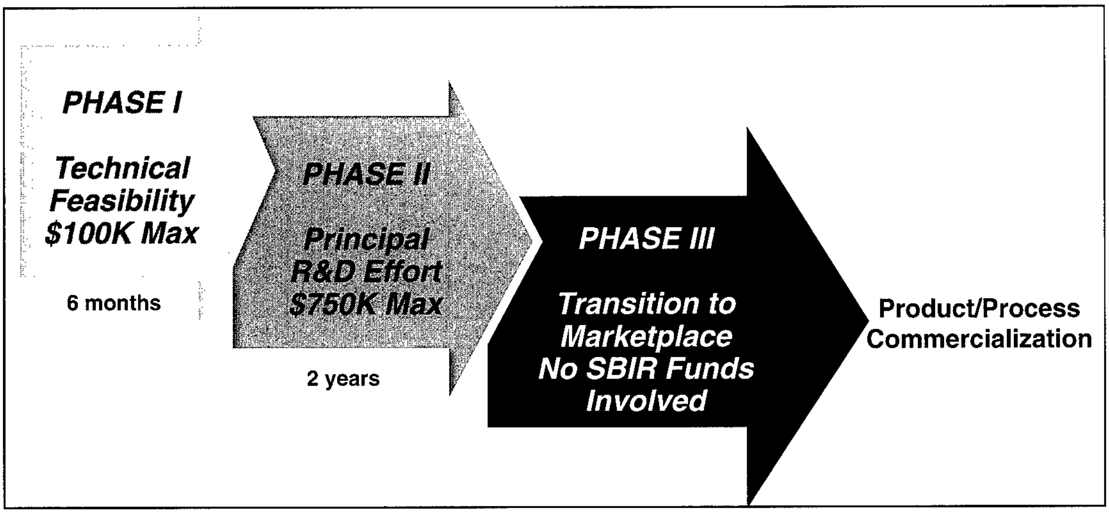
By law, all federal agencies having an extramural R&D budget exceeding $1 billion must participate in the SBIR Program. SBIR funds are set aside according to a certain percentage of the participant's extramural R&D budget. In FY96 the percentage was 2.0 percent. For FY97 and thereafter, the set-aside percentage will be 2.5 percent. The planned Army SBIR budget for FY96 was $86 million and for FY97 it will be approximately $93 million.

Each year, in cooperation with other DoD agencies, the Army generates and publishes a set of high priority topics in the SBIR Solicitation and invites small businesses to submit proposals against these topics. The SBIR Solicitation lists the topic opportunities, defines proposal formats, and states the proposal evaluation and selection criteria.

The SBIR Program is a three-phase program as depicted in Figure VII-1. Phase I determines the scientific or technical merit and feasibility of proposed concepts and typically lasts 6 months. Approximately 1 in 5 submitted Phase I proposals are selected for award. Phase I results are carefully evaluated and those Phase I performers showing the best promise may be invited by the Army to submit Phase II proposals. Phase II is a 2-year effort covering the main R&D effort—approximately one-half of the invited Phase II proposals are selected for award. Expected out of Phase II are results in the form of well-defined products or processes which have relevance to the Army/DoD or the private sector.

Phase III is the last step in the SBIR process. In Phase III the small business is expected to market and sell the products or processes developed during Phase I and Phase II outside the SBIR

Figure VII-1. Small Business Innovation Research (SBIR) Program: Flow Process



Program. No SBIR funding is provided in Phase III; however, the firm is free to pursue non-SBIR government follow-on contracts (sole-source or otherwise), or a leveraged combination of both non-SBIR government and private sector funding.

Since 1982, the Army SBIR Program has funded thousands of small businesses to provide innovative dual-use technologies. The program has been fully successful in meeting the Army's technology needs, while at the same time strengthening America's small businesses by accelerating their technologies into the marketplace. This process was greatly enhanced in FY96 by the Army's implementation of the SBIR 2-year pilot Fast Track Program, which is designed to accelerate the small firm's progress towards Phase III. Under the Fast Track Program, firms successfully identifying third-party matching funds for Phases I and II will receive interim gap funding (between Phases I and II) from the Army, as well as the Army's highest priority for selection and award of Phase II contracts.

2. Small Business Technology Transfer (STTR) Program

The STTR Program was established as a 3-year pilot program beginning in FY94 by the Small Business Research and Development Enhancement Act of 1992, PL 102-564. It has been reauthorized for FY97. Modeled closely on the SBIR Program, STTR is also a competitive three-phase program; however, its purpose is to incentivize small businesses to partner with researchers at universities, non-profit research institutions, or federally funded R&D centers (FFRDCs) to move innovative concepts out of the laboratory into the marketplace. At least 40 percent of the R&D work must be performed by the small business and not less than 30 percent by the research institution. The small business is the prime contractor and has overall responsibility for managing and performing the work.

The STTR Phase I is to determine the scientific, technical merit and commercial potential, and feasibility of the proposed cooperative effort. Phase I awards are for up to $100,000 and not to exceed one year. At the conclusion of Phase I, the Army invites the most promising efforts to submit Phase II proposals. The best of these are selected and awarded contracts to continue their R&D in Phase II. Beginning in 1996, those Phase I awardees who obtain independent third party funding commitments of funds for Phases I and II will be eligible for the STTR Fast Track and may receive matching interim gap funding (between Phases I and II) as well as matching Phase II funds. Phase II awards are for up to $500,000, not to exceed two years in execution. In Phase III the small business/research institution teams are expected to use private capital or non-STTR government funds, or both, to commercialize the results of their STTR-sponsored R&D.

By law, federal agencies with an extramural R&D budget exceeding $1 billion must participate in STTR. The STTR set-aside percentage remains 0.15 percent for FY97.

The DoD STTR Solicitation is released during the second quarter of each year. Army STTR topics are broad in scope, are based on critical technologies reflecting the Army's mission, and emphasize potential commercialization/dual-use applications. Eleven Army topics were included in the FY96 STTR Solicitation. They were carefully developed so as to represent the interests of all Army R&D organizations.

3. Army Domestic Technology Transfer (ADTT) Program

There is a long history of technology transfer from in-house Army R&D to commercial applications. For example, Army technologies form the basis for both the alkaline battery industry and the flexible-packaging industry for food preservation, which provide strong production bases for military needs. Today commercial sales of these items amount to many millions of dollars each year. Technology transfer has recently received increased emphasis within the Army, the Congress, and the current Administration as we have recognized the need to merge military and civilian technology and production bases to form a unified, strengthened, national capability. This policy helps maintain military capability in the face of decreasing funding and uses military resources to enhance national economic strength.

The initial formal requirement for technology transfer from federal laboratories was the Stevenson-Wydler Act of 1980 (15 USC 3701 et seq.). Its intent was to maximize the benefit of taxpayer investment in federal R&D. The Federal Technology Transfer Act of 1986 (Public Law 99-502) provided specific requirements, incentives, and authorities for federal laboratories to actively engage in technology transfer. It gave the director of each federal laboratory the authority to enter into Cooperative R&D Agreements (CRDAs) and to negotiate Patent License Agreements (PLAs) for inventions made at their laboratories. The National Technology Transfer and Advancement Act of 1995 (Public Law 104-113) amends these previous laws to provide additional incentives encouraging technology commercialization to both industry partners and federal laboratory inventors. This new law seeks to promote industry's prompt deployment of inventions created in a CRDA by guaranteeing the industry partner sufficient intellectual property rights to the invention and providing increased incentives and rewards to lab personnel who create new inventions.

CRDAs are only one of several tools used for technology transfer, but they are probably the most powerful. They make the technology, facilities, and people of Army laboratories available to a commercial partner at an early stage of development; provide a direct benefit to the Army's mission from the partner's effort; and perhaps most importantly, encourage direct interpersonal communication between scientists and engineers of the two sectors. These relationships had been discouraged in a Cold War defense culture separated by rules and customs from the larger technical culture, and an important task of the ADTT program is to overcome this culture gap.

PLAs are an important mechanism for commercializing inventions developed in Army labs. Each lab maintains a collection of patents developed by its scientists and engineers and markets those with potential commercial application. When licensed and commercialized, these inventions benefit consumers with new or improved products and increase the Nation's economic strength. Royalties are shared by the inventors (who receive the first $2,000 and thereafter 20 percent of royalties received) and the lab (which keeps most of the remainder). This reward structure provides a strong incentive for commercialization, which is beginning to change the behavior of both individual inventors and lab management. Responding to this increased interest in the labs and increased recognition of the importance of spin-off by Congress and the Administration, the ADTT program is initiating more aggressive marketing strategies to increase patent licensing.

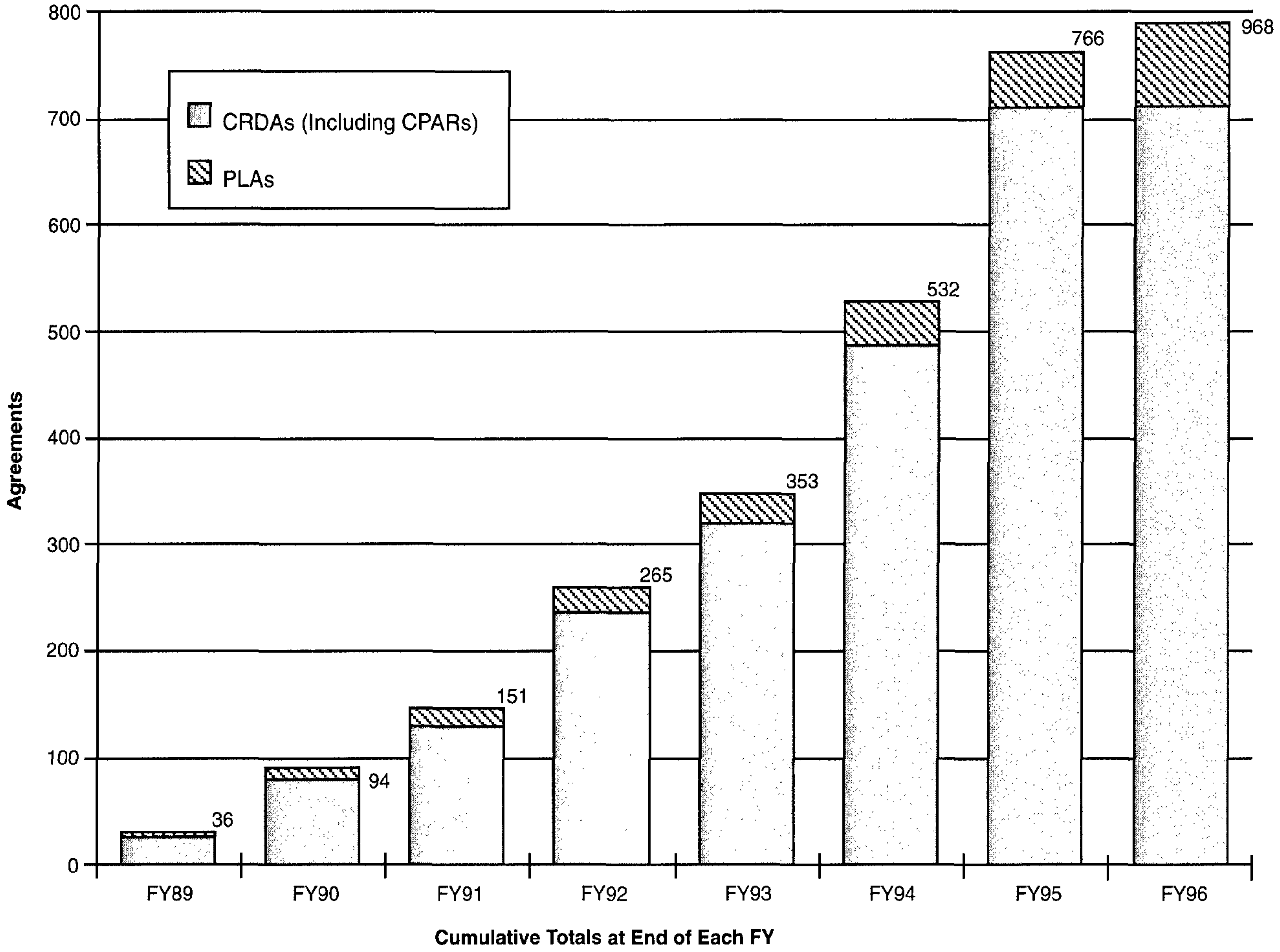
The Construction Productivity Advancement Research (CPAR) Program is a cost-shared, collaborative R&D partnership between the U.S. construction industry and the Corps of Engineers. The Program is designed to enhance construction industry productivity and innovation and benefit both the industry and the government. The Corps is authorized to utilize the capabilities and facilities of its R&D laboratories to pursue joint R&D, demonstration, and commercialization/technology transfer projects with an industry partner. The projects are based on ideas from the construction industry, and the Corps may provide up to one-half the cost of a project. Recent additional authority permits the Corps to utilize contributions of other federal agencies in the program. Through FY95, 72 projects were selected, with the industry providing $42 million and the Corps $27 million. CPAR products are being utilized by the construction industry and are increasing productivity and reducing costs. CPAR funding for FY96 was deleted by the Congress, and the program is currently inactive, except for the completion of the remaining projects.

The Army has been a leader in technology transfer efforts from federal laboratories to the public and private domestic sectors for many years. Each Army laboratory and RDEC has an Office of Research and Technology Applications (ORTA) to actively seek technology transfer opportunities and serve as a point of contact for potential users of its technology. The functions of an ORTA include assessment of laboratory technology which might have commercial applications, assistance to state/local governments, and the development of CRDAs and PLAs in conjunction with private sector and laboratory technical and legal staffs. The ADTT program is intended to work through the decentralized but coordinated activities of the ORTA at each of the Army's laboratories and centers.

During FY96, 183 CRDAs and 19 PLAs were approved, for a total of 202 new agreements. Since most of the agreements negotiated since the inception of the program are still active, we track the cumulative totals, which were: 895 CRDAs including CPAR CRDAs, and 73 PLAs for a total of 968 agreements (see Figure VII-2). Total patent royalty income since inception of the program was $927,000, of which $198,000 was paid to individual inventors, with the remainder to their labs.

The booklet "Army Technology Serving Society," published in FY95 presents over 40 technology transfer success stories. By demonstrating the major benefits of this program to both our partners and the Army, it has

Figure VII-2. Army Accepted CRDAs/PLAs



generated great interest among potential partners and among brokers who can help match the Army with partners.

Some specific examples of recent cooperative efforts include:

- The Army Research Laboratory has teamed with a commercial partner to build a new rescue cutter with a laser-ignited pyrotechnic cartridge that provides massive energy to cut through steel and other debris. This self-contained battery-powered tool can be used to free victims trapped in wreckage after an accident or natural disaster. This technology originated in efforts to make large guns safer and more reliable by replacing the burdensome and sometimes unreliable primer of current gun systems.
- The Corps of Engineers Waterways Experiment Station (WES) awarded patent licenses to three companies in FY96 to manufacture and market the dual-mass dynamic cone penetrometer (DCP). This WES-developed device is used to determine in situ soil shear resistance (shear strength) for both high strength granular road and airfield pavement base layers and weak underlying subgrade soils. The DCP index obtained is then correlated with the more common California Bearing Ratio (CBR) index. The DCP allows rapid on-site determination of shear strength versus depth, thereby allowing rapid evaluations of existing flexible or unsurfaced roads, runways, taxiways, and hardstands by the military and civil sector.
- Computational Vision Model technology was developed by the Tank-Automotive RDEC as a tool for analyzing the effectiveness of camouflage on military vehicles. TARDEC is working with one of the Big Three auto makers to adapt this model to one that perceives moving vehicles in traffic scenes. This technology may help reduce accidents on our highways by allowing auto makers to design those aspects most noticed by the human eye into automotive shapes and colors.
- The Walter Reed Army Institute of Research and a small biotechnology company have developed a dipstick assay diagnosis system that can provide simple, rapid, and accurate identification of serious tick-borne diseases. Dipstick assays have been developed for all three groups of rickettsial diseases (typhus, scrub typhus, and spotted fever) and work is under way to prepare a dipstick for detecting Lyme disease as well.
- Benet Laboratories scientists and engineers capitalized on current and past research efforts in weapons research, gun vibrations, munitions loading technology, and neural networks to develop a specialized sensor/switch which can detect the unusual vibrations characteristic of a brain seizure and set off a remote alarm. This device is being evaluated on a child afflicted with a rare form of epilepsy which causes small, almost invisible seizures, often accompanied by difficulty in breathing, thus necessitating 24-hour monitoring. The new device may eliminate the need for constant monitoring and allow parents to respond only when alerted by the alarm.
- The Edgewood RDEC and private sector partners have developed a rugged, compact infrared sensor that could filter out existing background information and identify harmful airborne chemicals without a zero-gas (pure air) reference. With this technology, vapors from industrial smokestacks or the perimeter of a plant site can be continuously monitored. Placed on a mobile platform when conditions are dangerous, the sensors can be moved to an industrial spill or fire to determine possible poisonous or toxic emissions or moved through a site to find toxic leaks.

In the future, the Army will continue to support ADTT through strong management support of active ORTAs in conformance with both the letter and spirit of technology transfer legislation. The ADTT Office coordinates ORTA efforts and provides training on marketing and technology portfolio management.

Organized efforts are also under way within the technology transfer community to develop improved ways of assessing the value of collaborative agreements. The Army is an active member of the Working Group on Measurement and Evaluation of the Interagency Committee on Technology Transfer, led by the Department of Commerce. This group is developing a uniform, well-designed set of descriptors and metrics for assessing the value of cooperative efforts as well as other technology transfer mechanisms at all government agencies. A longer-term effort is under way to re-late identifiable events, such as a patent granted or licensed, to larger societal benefits, such as economic growth, as well as to mission enhancements.

The Army will seek to increase its number of quality collaborative agreements. Army CRDAs should be established to develop technology with an obvious value, either in commercial application for improving the U.S. competitive position or in applications for the public good, such as in health, education, or environmental areas. Additionally, CRDAs should be sought in technology areas of strategic importance to the laboratory or center.

The Army is undertaking to coordinate and increase its overall marketing efforts for technology transfer. Individual laboratories and centers are encouraged to aggressively market the expertise and unique capabilities and facilities of their organization. Attendance at technology transfer shows and conferences is an important outreach effort. The Army is expanding its marketing efforts in conjunction with the Federal Laboratory Consortium, a formal government-wide network of all ORTAs, which supports extensive outreach and referral efforts. In particular, we are targeting relationships with high technology small businesses.

4. Technology Transfer in Medical Research and Development

The primary purposes of military medical R&D are preventing injury and illness in the field and sustaining life and health. However, there is probably no other DoD program whose research results are so directly applicable to the worldwide civilian community. Advances in antimalarial drugs, vaccines for many diseases, blood and tissue substitutes, and the treatment of trauma are all of direct and present benefit to people everywhere. The benefits are not limited to the United States; for example, DoD research teams deployed in Egypt, Taiwan, Indonesia, Thailand, Malaysia, Brazil, and Peru have worked directly on civilian health problems that not only are threats to the future deployment of American troops, but also are presently infecting local populations. Medical R&D also contributes to establishing national and international standards such as nutritional requirements of special populations, exposure to occupational health hazards, and development and demonstration of modeling technologies for predicting the effects of exposure to health hazards. For example, the Department of Transportation has used the Army's blast over pressure injury model to predict injuries from driver and passenger air bags.

The Army's first collaborative efforts in medical R&D were basic screening and testing agreements, under which a company or university would submit compounds for testing for a specific property, such as antimalarial activity. These early agreements quickly evolved into more extensive collaborative efforts where each partner would expend resources towards the development of a product and share the results of its efforts to meet the Food and Drug Administration's regulatory process. The development of mefloquine is a classic example of an early cooperative effort between the Army and industry which predates the Federal Technology Transfer Act. Each party funded its own preclinical and clinical studies with its own unique resources and shared and consolidated the data. The Army medical research and development program over the past decades has fostered thousands of cooperative relationships with academia and industry. With this history of extensive collaboration it is not surprising that this program continues to pace all of DoD in its collaborative efforts.

The Army's medical research and development program is rapidly evolving into the next generation of collaborative efforts: (1) pursuing cooperative research and development agreements coupled with patent license agreements for products and technologies which have both military and commercial applications, and (2) spinning off products and technologies predominantly with commercial applications through patent licensing agreements. The Army has numerous compounds which exhibit activity for multiple indications, some of which have commercial value and some of which are of value to the soldier in the field. For example, the Army is developing several compounds which appear to be active against malaria, leishmania (a problem for some Desert Storm veterans), and pneumocistis (which kills many AIDS patients). A collaborative effort on such compounds with multiple indications avoids duplication and allows U.S. industry and the Army to leverage each other's resources. The Army also has several products or technologies useful to the research and commercial communities, from vaccine production tools to qualitative and quantitative assays. Spinning off products and technologies with predominantly commercial applications or of general utility to the research community allows the Army to harvest a financial and societal return on its investment in the basic science, without diverting scarce resources from research with a higher military priority.

The U.S. Army Medical Research and Materiel Command (USAMRMC) encourages research in relevant fields at colleges and universities, and cooperates with research efforts of the NIH, the NSF, and other government agencies. These research programs complement and exploit civilian science and technology efforts over the full research and development spectrum. The commercial sector is encouraged to address problems of military interest through the Small Business Innovation Research Program. The Federal Technology Transfer Act is the authority for numerous USAMRMC Cooperative R&D Agreements, primarily with pharmaceutical, chemical, and biotechnology firms. Medical R&D is an international program that most typifies broad and effective current and potential opportunities both in developing and developed nations; the USAMRMC participates in information and data exchange programs, cooperative developments, NATO comparative tests and foreign weapons evaluations, and symposia and meetings.

C. Technology Cooperation with Non-Profit Institutions

Universities provide advanced scientific and engineering education which is critical to military security and economic strength, and have traditionally performed a major part of the nation's long-term basic research. Since the 1940s, the Army has supported academic work in areas of potential military interest. In response to evolving social, economic, and budget realities, Army support to universities is emphasizing more focused effort on Army problems, more effort to transition research results into commercial or dual-use products, and more support to people and institutions traditionally underrepresented in the national scientific and engineering enterprise.

To contribute to its own and the nation's future strength, the Army is increasing its efforts to support interest in science and engineering careers in colleges and universities, high schools, and elementary schools.

The Army cooperates with non-profit institutions (including universities) by means of CRDAs and PLAs (see Section VII.B.3), and the Army STTR program uses small businesses to commercialize technology developed in these institutions (see Section VII.B.2).

The Army is the government sponsor for two federally funded R&D centers (FFRDCs) and, as appropriate, uses the unique capabilities of FFRDCs sponsored by others.

1. Programs with Academia

The Army's 6.1 program, approximately half of which supports basic research at universities, is a key leveraging mechanism. Through its funding of university research scientists, engineers, and their students the Army gains a window on the country's science and engineering frontiers. Without question, these research investments will produce results having an enormous impact on the Army's future capabilities—through the emerging technology areas some of these funds help to support, through breakthroughs, and through discoveries not even imagined today. This program is described in more detail in Chapter V. The Army also maintains a European Research Office and supports a small amount of research at universities in Europe and Japan, in order to gain access to unique foreign capabilities (see Section VII. F).

a. University Research Initiative (URI) and Centers of Excellence (COE)

In addition to providing support to individual researchers, the Army sponsors research through two university-centered programs: the Army Centers of Excellence (COE) and the series of DoD projects known as the University Research Initiative (URI). Both address specific Army needs (see Figure VII-3). The URI's S&E education programs also address this country's need to increase its pool of advanced scientists and engineers by supporting nearly 400 S&E graduate students annually.

University COEs provide an attractive institutional mechanism for Army support to graduate-level research and education. Moreover, close interactions with Army R&D organizations are emphasized, so that the center technical staffs gain a greater appreciation of user needs, while the Army R&D community interacts easily with additional peers. The Army's investment in these centers is highly leveraged, for the centers have attracted additional sources of support. Through the Army and URI centers, the Army participates with more than 30 American universities. Both the COE and the URI are described in more detail in Chapter V.

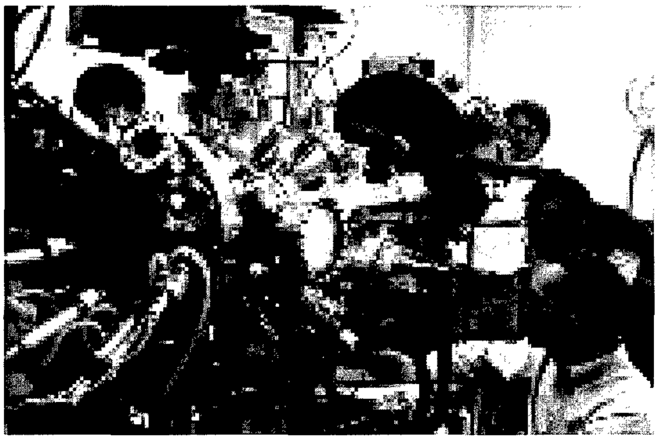
b. Interactions with the National Science Foundation

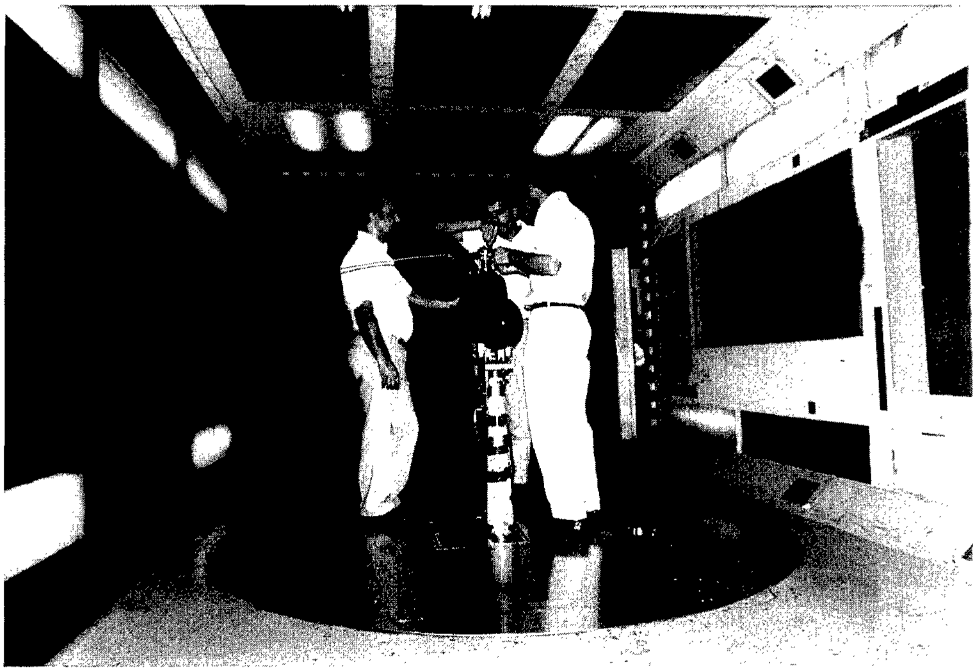
Through a memorandum of understanding, the Army and the National Science Foundation (NSF) formed a consortium which includes eight universities to attack critical problems in high-speed microelectronics, millimeter waves, and communications research. NSF provides grants, and the Army provides access to what is considered DoD's best microelectronics fabrication facility. While there, students and their mentors conduct research that benefits academia and the government. Also, the Army Research Laboratory is an industrial board member of the Software Engineering Research Center sponsored by NSF.

2. Historically Black Colleges and Universities and Minority Institutions

Recognizing that historically Black colleges and universities and minority institutions (HBCUs/MIs) are a national resource with high enrollments of underrepresented minorities, the Department of Defense has encouraged its agencies to develop programs which will enable these institutions to increase the number of minority graduates in the physical sciences, mathematics, and engineering.

Figure VII-3. Funding for University Research Efforts Includes the Army Centers of Excellence and the University Research Initiative Centers





It is Army policy that:

- At least five percent of RDA funds going to higher education institutions are to be awarded to HBCUs or MIs.
- Each RDEC/laboratory is to foster a linkage agreement with an appropriate HBCU/MI.
- ARO will facilitate research collaborations between HBCU/MIs and Centers of Excellence (COEs).
- All new Army COEs are to have an HBCU/MI member.
- Information sciences and training research COEs are headed by HBCUs.
- Each Army COE is to have a proponent laboratory/RDEC which provides the COE Executive Advisory Board Chairman.

The AMC has made considerable progress in achieving these goals. In addition to exceeding the 5 percent funding goal, several significant programs have been established.

- All proposals for Federated Laboratory partners (see Section VII.E) required significant HBCU/MI participation. Proposal evaluations considered plans for integrating the HBCU/MI's program with that of the other partners, and the likelihood of educating more highly qualified minority engineers and scientists.
- Cooperative programs have been established between major universities and historically Black colleges and universities. A major one is the Army High Performance Computing Research Center contract with the University of Minnesota, involving subcontracts with Howard University, Jackson State University, Alabama A&M University, and Clark Atlanta University at a funding level of more than $4 million for research, equipment, and infrastructure support. This initiative is a prototype for future cooperative research programs.
- The HBCU Center of Excellence program, launched in 1991 by ARO, brings together a critical mass of university researchers to advance militarily relevant technologies. In FY92, ARO awarded two competitive grants to establish the first HBCU/MI Centers of Excellence at Clark Atlanta University and Morris Brown College. Each Center was supported at $0.75 million per year for 5 years. Clark Atlanta specializes in information sciences to provide the Army with the support needed to collect, sort, integrate, manage, and evaluate increasing quantities of automated information used in battle management and combat operations. Morris Brown specializes in research on Army training and how future soldiers can maintain peak proficiency during combat operations.

In FY93, the AMC consolidated its HBCU/MI research and development program at ARO, which has resulted in some new approaches to working with the HBCU/MI community. In February 1994, ARO published the first edition of "AMC Guide to Programs" especially for HBCUs/MIs. The Guide synopsizes research programs of ARO, the Army Research Laboratory, and each AMC RDEC, and advertises other opportunities for the schools to work with the Command, such as summer programs, cooperative programs, and equipment transfers. Another facet of the ARO/AMC program is recognition of accomplishments derived from research programs with HBCUs/MIs. In that regard, ARO has prepared a full-color brochure of HBCU/MI accomplishments.

The Army Materiel Command's research programs and other opportunities for HBCUs/MIs are the most innovative of the entire defense department. Through the "one-source" approach, the Command has collected and focused its efforts into a model program.

3. Federally Funded Research and Development Centers (FFRDCs)

FFRDCs perform, analyze, integrate, support, and/or manage basic or applied research and/or development, and receive at least 70 percent of their financial support from the federal government. FFRDCs have access to government and supplier data, employees, and facilities beyond that which is common for a normal contractual relationship. (A master list of these activities is maintained by the NSF.) The Army is the government sponsor for two FFRDCs: the Arroyo Center, a research division of RAND, Santa Monica, California; and MITRE Corporation's C3I operating division in Washington, D.C.

Staff at the Arroyo Center perform studies and analyses for the Army. This FFRDC's mission is to provide objective and independent analytical research on major Army policy, management, and technology concerns, with an emphasis on mid- to long-term problems. Efforts include policy and strategy analyses; research within the framework of the Army's future force needs and employment concepts; analyses and testing of alternative policies for manning, training, and structuring the Army of the future; analyses of issues associated with future readiness and sustainability; and studies in applied technology. These analyses identify and assess the ways in which technological advances can enhance the future Army's capabilities. Examples in this last area include an assessment of advanced light armored vehicles, terrorists and biological weapons in the 1990s, and the Army's role in space.

MITRE Command, Control, Communications, and Intelligence (C3I) FFRDC has two divisions, the MITRE Bedford Division sponsored by the Air Force and the MITRE Washington Division sponsored by the Army (the "primary sponsor" is in OSD). The mission of this FFRDC is to conduct studies and analyses, systems engineering support, and laboratory experimentation based on sponsors' requirements. MITRE conducts its own In-House Research and Development, tailoring the programs to sponsors' missions. An important link between the Air Force and the Army, MITRE provides an objective, technical basis for the conception, analysis, selection, design, and evaluation of information and communications systems.

4. Outreach Programs

Studies by the National Science Foundation and the National Academy of Sciences have indicated that in order to meet the scientific and economic challenges expected in the year 2000 the nation will need to attract and retain more students in degree completion activities in science, mathematics, and engineering. Approximately 70 percent of the adults entering the work force between now and the 21st century will be women and minorities. Yet, women and minorities are two groups historically underrepresented and underutilized in science and engineering. To counteract this trend, DoD task force studies have urged the creation of intervention programs designed to increase the availability of scientific, engineering, and technical skills in the DoD work force. A number of these Army outreach efforts are described in this section.

a. Women in Science and Engineering

There is a significant underrepresentation of women in engineering and the physical sciences, compared with their participation in the general workforce. Despite significant increases during the last generation, only about 9 percent of all working engineers are women, and in recent years the proportion of new women engineering graduates has remained constant at about 16 percent. Absent significant intervention or major social change, the proportion of women in engineering is therefore likely to increase gradually and then level off. Perhaps because of their scarcity and/or because only the best survive, women engineering graduates receive 103 percent of the starting salary of men.

The Army has outreach activities whereby it employs women college students from local universities, studying engineering and the sciences, in a cooperative education program that alternates school and work cycles. High school and college summer employment opportunities are also available (Figure VII-4). In addition there are employment programs for women instructors in high school and higher education who are interested in keeping current in their areas of technical expertise.

The Army actively ensures promotion opportunities for both women and minorities. All proposed selections to senior- and executive-level science and engineering career positions are carefully reviewed before the development of candidate referral lists. A mandatory recruitment/outreach plan is formulated to locate all best qualified women and minorities. The entire process is audited at the Army major command level.

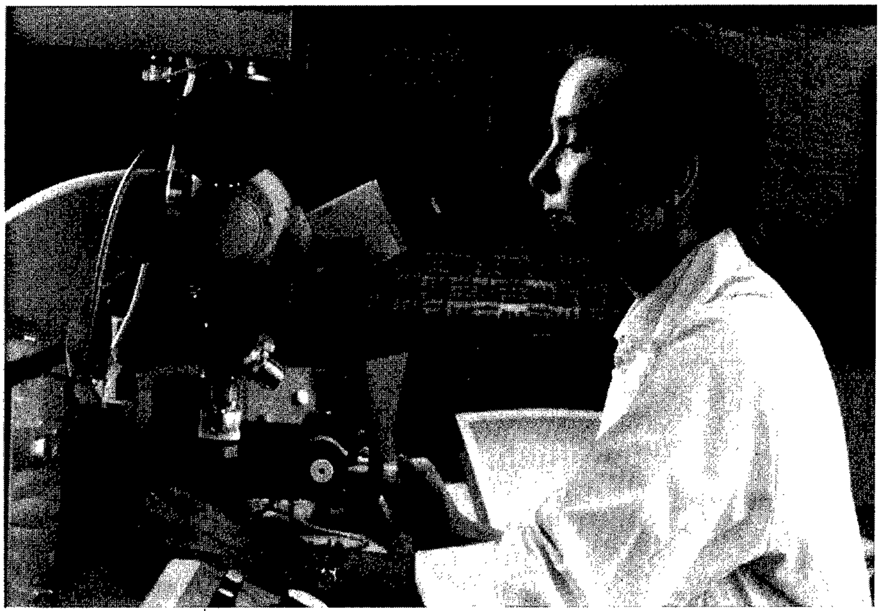
b. Youth Sciences Activities

A major need for the future U.S. competitive edge is maintaining or increasing the scientific and technical human resources available to both the government and private sectors. To accomplish this, education, especially in science, mathematics, and technology, is critical.

Many Army laboratories have outreach programs which are actively supporting innovative ways to improve science and technology education and improve the cost effectiveness of local school systems. These initiatives to support educational systems, at all levels, are accomplished under a wide variety of established programs such as adopt-a-school, education partnerships, and student/faculty employment programs.

Services provided by hundreds of Army scientists and engineers have helped to improve science, mathematics, and technology education through such contributions as technical lectures, career education, science fair judges, field trips, mentors for student research projects, library support, computer support, loaning/donating surplus equipment, providing students an opportunity to work on defense laboratory research projects for academic credit, and teaching classes or assisting in the development of courses and materials.

Figure VII-4. Army Outreach Programs Include Attracting Women Scientists and Engineers



A key element of education is the classroom teacher. To keep up with the changing world of science and technology, classroom material taught must be continually updated so that students are prepared to take their places in a more technologically complex world. This means teachers have to be updated. They can't teach what they do not know. They can't prepare their students for a career in a work world they haven't seen. Army laboratory personnel are working with teachers from school systems throughout the nation to enable them to experience firsthand some of the recent changes in science and technology and to develop methods for discarding out-dated information and incorporating the new material into the classroom.

School systems have derived substantial benefits from direct involvement with key scientists and engineers at Army laboratories, as evidenced by numerous awards, certificates, and letters of appreciation for Army support in partnership programs in math, science, and technology programs with local school systems.

The Army also sponsors a number of specific youth programs at the high school and pre-college levels to promote participation in science and engineering activities. For example:

- The Junior Science and Humanities Symposium (JSHS) was initiated by the Army in 1958 and joined by the Office of Naval Research in 1995. Its activities promote research and experimentation at the high school level, identify and recognize talented youth and teachers, and increase the country's pool of young adults interested in pursuing careers in the sciences. JSHS reaches over 10,000 students and 250 teachers annually.
- The Uninitiates Introduction to Engineering (UNITE) program provides socially and economically disadvantaged secondary school students with tutorial assistance, primarily in mathematics. Through their participation, these students can acquire the prerequisites for beginning science and engineering careers in college. The program began in 1980. At least 2,254 students have participated during its first 14 years. Of these, 71 percent had enrolled in college through 1994, with 51 percent enrolling in technical fields, 44 percent in engineering, and 5 percent pursuing the humanities.
- The Research and Engineering Apprenticeship Program (REAP) is a cooperative work-study program that gives high school students hands-on experience in R&D activities through interactions with mentors. Drawn

from socially and economically disadvantaged groups, as defined in P.L. 95-507, these students are selected on the basis of their potential to pursue careers in science and engineering. The program began in 1980. At least 1,700 students have participated through 1996. Of these, 90 percent entered college, with 86 percent of these undertaking engineering or science studies.

- The International Mathematical Olympiad (IMO) was started by eastern European countries following World War II. As a means to encourage young mathematicians, the United States began participating in 1976 with the selection of an American team under the auspices of the Mathematical Association of America. Along with the Navy, the Army contributes to this effort by providing funds. Annually six American students (from over 400,000 that compete) and three coaches travel to the site of the Olympiad for approximately 10 days of individual competition. American students often achieve first place honors at the IMO, which is one of the most prestigious competitions in mathematics at this level. In 1994, each U.S. team member scored a perfect score on their testing for the first time in the history of the program.

- Since 1960, the Department of the Army has sponsored special awards in the nationwide Science and Engineering Fairs as a means to stimulate and encourage the future technical development of our nation's youth. Army personnel participate as judges in regional, state, and international fair competitions and present awards on behalf of the Secretary of the Army. The International Science and Engineering Fair (ISEF) brings together two students from each of approximately 400 regional and state science fair competitions that involve over 100,000 high school students. Winners in 13 scientific and engineering categories are each awarded a certificate of achievement, a $3,000 prize, and a gold medallion. In addition, one student is selected to attend the London International Youth Science Forum at the University of London, where students from over 35 nations participate in a 2-week program of scientific lectures and cultural tours. Two students are selected to visit Tokyo as part of an exchange program between the United States and Japan, where the two Army winners are recognized at the Japan Student Science Awards Ceremony. The three trip winners each receive a certificate of achievement, a medallion, a $3,000 prize and $150 from the Association of the United States Army.

- The National Science Center (NSC), established by Public Law 99-145, is designed to increase interest in science, math, and technology among students, improve the skills of teachers, and provide math and science education support in the classroom. The Center offers hands-on workshops/camps for students and teachers in science, math, electronics, and computers. In addition, the NSC operates a Discovery Center which offers school groups and the general public interactive experiences with scientific exhibits. A mobile version of the Discovery Center travels to schools across the country. The NSC also reaches out nationally with satellite teleconference programs on science education. Finally, the Center offers a Science-by-Mail program, which encourages a pen pal relationship between students and scientists, and a STARLAB program, which ends portable planetariums to classrooms for instruction in space science, astronomy, geography, and biology. At the direction of the Chief of Staff of the Army, the NSC is expanding its programs to target audiences in inner cities and rural areas nationwide. Over 80,000 participants will be touched by NSC programs, both on and off site, in 1996.

5. Army Science Conference

The twentieth Army Science Conference, sponsored by the Assistant Secretary of the Army for Research, Development and Acquisition, was held at the Norfolk Convention Center, 24–27 June 1996. The conference theme was "Science and Technology for Force XXI." It featured presentations of papers judged as best among those submitted by Army scientists and engineers. This conference continued the effort to interact with industry and academia that was established at the 18th Army Science Conference. In an era of austere budgets for all R&D communities, the free exchange of ideas, efforts in cooperative research, and the formation of consortia between the Army and extramural partners are essential for our continued history of technological excellence. The transfer of technologies, to and from all partners, is essential not only for the national defense, but additionally for an enhanced national economic competitiveness. The Army Science Conference, held every other year, continues to provide a viable forum that addresses these bedrock issues.

D. Technology Leveraging Programs

As mentioned earlier, Army S&T comprises less than one percent of the total National Investment in R&D, thereby requiring the Army to leverage external R&D activity in order to meet its mandatory warfighting needs.

R&D that is external to the Army comes from a variety of sources, including:

- Other federal government organizations (both DoD and non-DoD government organizations).
- Universities and non-profit organizations.
- U.S. industry.
- Foreign sources of all the above types.

As will be seen in this section, the Army Technology Transfer Program systematically leverages each of these important sources of technology.

Ultimately the Army's goal is to form cooperative programs with these sources. In some cases, the cooperative program may appropriately involve cost-sharing activities. In other cases, it may only influence the direction of development by the external source, or may maintain a "smart buyer" capability within the Army. Whatever specific form the leveraging employs, it is based upon a foundation of Army experience with past programs, in-house experts, and information resources that provide timely data for development of cooperative programs.

This Section and Section VII.E describe the Army's approach to technology leveraging with the major external sources of technology available within the United States. Section VII.F describes the Army's approach toward leveraging foreign sources of technology.

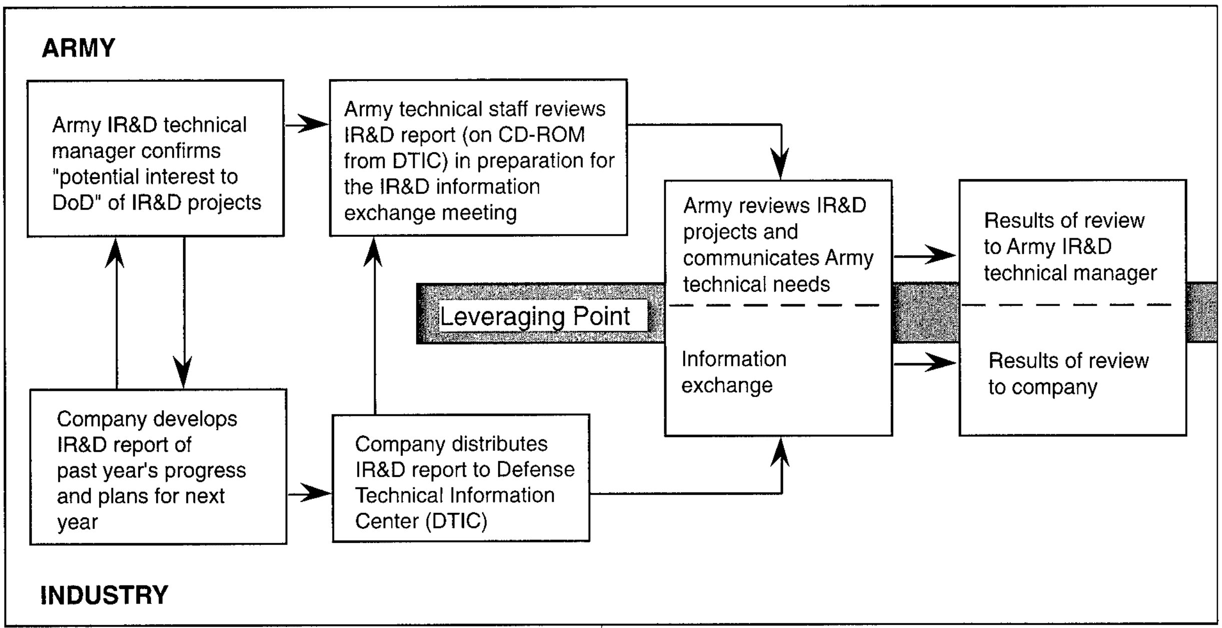
1. Independent Research and Development (IR&D) Program

IR&D activities are planned, performed, and funded by companies in order to maintain or improve their technical competence or to develop new or improved products. Industry IR&D efforts amount to more than $2 billion annually. A portion of a company's annual IR&D expenditures and its companion Bid and Proposal (B&P) costs can be recovered later in the overhead portion of its contracts with commercial concerns and with DoD. The FY92 Defense Authorization Bill simplified the procedure used to reimburse companies for relevant IR&D work. Beginning in FY96, contractors were reimbursed for up to 100 percent of their IR&D expenditures that meet "potential interest to DoD" criteria.

Prior to FY93, company IR&D programs were assigned to a lead Service for purposes of technical review and cost-recovery negotiations. The new law eliminates these assignments and focuses on utilization of industry's significant IR&D technology resources through technical interchange meetings. IR&D technical interchange meetings are arranged by mutual agreement of the company and the government to review and discuss a focused set of technology and/or product development projects. These meetings promote face-to-face technical interaction between contractors and the government, provide feedback to companies so that IR&D activities are aligned with future government needs, and permit government participants to visit the contractors' facilities and view operations. Many of the Service and company assignments established prior to FY93 have proven to be mutually beneficial and will be continued voluntarily. Company and Government personnel are free to continue frequent informal dialogue and technical information exchange even though they no longer maintain a formal assignment to one another. There is no required frequency of meeting, but most contractors express a desire to meet at least annually. (The Army IR&D information exchange process is shown in Figure VII-5.)

The projected downward trend of DoD expenditures affects the future of industry IR&D

Figure VII-5. Independent Research and Development (IR&D) Communication Process



activities. Rigorous cost competition in the defense industry has caused pressure to reduce overhead (including IR&D), and decreasing sales have reduced the base against which IR&D costs can be charged. The likely result—erosion of industry's IR&D technology base—led to the new cost recovery process and a broadened set of cost-recovery criteria as means to limit this loss of U.S. technical strength and encourage interest in defense conversion and in dual-use technology. The new criteria for reimbursement are to:

- Enable superior performance of future weapon systems and components.
- Reduce acquisition costs and life-cycle costs of military systems.
- Strengthen the U.S. defense industrial and technology base.
- Enhance U.S. industrial competitiveness.
- Promote the development of critical technologies (as identified by DoD).
- Increase the development of technologies useful in both the public and the private sectors.
- Develop efficient and effective technologies for achieving environmental benefits.

Improved communications between industry and government on IR&D is the heart of successful leveraging of IR&D, and continues to be an area of broad emphasis through frequent interaction of Army leadership and industry IR&D representatives. Recent improvements to the IR&D reporting and review processes will significantly enhance the Army's ability to strategically leverage IR&D developments. These improvements include CD-ROM technology applied to the IR&D data base at the Defense Technical Information Center (DTIC), a new DoD Instruction on IR&D that will ensure more complete reporting of IR&D to government and more complete review of appropriate IR&D by the Army. An IR&D Web site on the Internet is coordinated by the Air Force IR&D manager. This service will provide contractors access to relevant DoD planning information to focus their IR&D expenditures on relevant DoD technology needs. The bulletin board will also contain a schedule of IR&D Information Exchange meetings to inform and encourage government personnel participation in these important information exchanges with contractors as well as other government personnel.

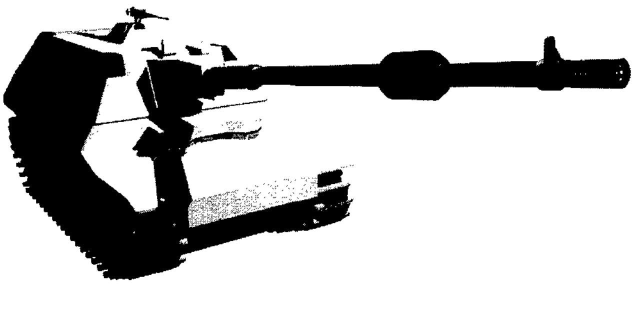
Prior to FY94, the Army received IR&D technical information through several means: paper reports submitted by industry, on-site review meetings, access to the IR&D data base at DTIC through dedicated computer terminals connected to the DTIC mainframe computer, and the Army IR&D database maintained by ARO. The IR&D data base on CD-ROM, issued by

DTIC beginning in FY94, has significantly enhanced the Army's ability to leverage IR&D. The CD-ROM contains the entire data base of current industry IR&D technology developments, and permits every Army activity to maintain the complete IR&D data base of industry's IR&D expenditure on a personal computer. Once full industry IR&D reporting to DTIC is achieved, as emphasized in the new DoD Instruction on IR&D, the CD-ROM will become a reliable and comprehensive source of industry technology.

Through utilization of the IR&D data base on CD-ROM, local Army IR&D managers should be able to better target IR&D projects of interest, vector those project write-ups to local scientists and engineers, and follow-up positive in-house response by establishing technical information exchange meetings. These meetings are the vehicle whereby the Army communicates technology needs to industry, and industry communicates IR&D progress and plans to Army scientists and engineers. Results of this process are Army programs and systems enhanced by IR&D and industry IR&D more focused on Army technology needs.

There are many "Success Stories" of technologies and system concepts developed or matured under IR&D which have been fielded by the Army. A recent example is the Crusader Program, formerly the Advanced Field Artillery System and the Future Armored Resupply Vehicle (see Figure VII-6). Many of the supporting technologies, including the basic concepts for these vehicles, were initiated in company IR&D programs. Some of the basic technologies which form the performance base for the Crusader in meeting its direct and general fire-support missions include the regenerative liquid propellant gun and its propellant, advanced techniques for technical and tactical fire control, MIMIC chips for fuze processing, polymer reinforced lightweight vehicle structures, and automatic ammunition handling and man/machine interface technologies.

Figure VII-6. Crusader Self-Propelled Howitzer



2. Advanced Concepts and Technology (ACT II) Program

The Army of the future faces the challenges of an uncertain political landscape against a backdrop of rapid technology growth. To explore the possibilities of the future while maintaining its warfighting strengths, the Army today has brought together a unique team to define the technologies that will shape the smaller, Force Projection Army of the 21st Century.

This team is comprised of the Army's Training and Doctrine Command (TRADOC) Battle Laboratories (BLs) and the Army's Research, Development, and Acquisition Community. Together, they are helping define the technology that will lead the Army to its Force XXI vision.

The Army's Advanced Concepts and Technology II (ACT II) Program enables direct industry involvement in this important endeavor. ACT II supports Battle Lab experiments through competitive funding of industry's most advanced technologies, prototypes, and nondevelopmental items. Ultimately, the Army selects proposals that demonstrate the greatest potential to fulfill warfighting capability requirements.

ACT II is sponsored by the Army Chief of Staff and the Assistant Secretary of the Army for Research, Development and Acquisition. The Army Training and Doctrine Command (TRADOC), the Army Materiel Command (AMC), and the Army Research Office (ARO) collaborate to build ACT II partnerships between the Army, industry, and the academic community.

The objective of the ACT II program is to address Army concerns using technologies that are mature or nearing maturity in the commercial sector. The program provides funding to demonstrate the technical feasibility of such technologies that, if successful, can either be integrated as part of the regular funded Army research and development (R&D) program, be selected to enter into the Army Warfighting Rapid Acquisition Program (WRAP), or be transitioned to an end item. ACT II does not fund established technology base programs, but seeks unconventional approaches to address Army needs. This access to the commercial market is intended to shorten the acquisition cycle and reduce the development cost which, under the conventional acquisition process, often requires long lead times for a research idea to reach the soldier. Because of its small size in comparison to conventional development programs (a maximum of $1.5 million per project), the ACT II program generally supports those highly leveraged efforts that appear likely to have an important impact on the Army if successful.

The ACT II program provides seed money for proof-of-principle demonstrations of high-risk/high-payoff concepts proposed by non-Army sources. Such efforts provide an opportunity to try unconventional approaches and/or technology not currently supported in the mission-oriented Army programs. ACT II projects are frequently cost-shared or leveraged efforts partly supported by others.

The ACT Committee was established in 1974 by the Army Deputy Chief of Staff for Research, Development and Acquisition; with abolition of that office, the Assistant Secretary of the Army for Research, Development and Acquisition (ASARDA) directed the Army Materiel Command (AMC) to manage ACT for the benefit of AMC and the Chief of Army Engineers.

Beginning in FY94, the program was recast as ACT II to provide direct support to the TRADOC Battle Labs (BLs) and the Chief of Staff of the Army's Louisiana Maneuvers (LAM) Task Force. With the user more actively involved, ACT II allows better evaluation of new capabilities enabled by ACT II technologies, and provides more responsive support from the RDTE community. The ACT II program provides funding and a mechanism for industry and academia to demonstrate mature technologies, prototypes, interfaces, software, and/or systems for assessment by the BLs as explained in Chapter II.

Proposals are centrally solicited using a Broad Agency Announcement (BAA) as prepared by the Army Research Office. The BAA requests that prospective offerors initially submit a two-page concept paper highlighting the technical and warfighting merits of their proposal. Those proposals ranked most desirable in terms of warfighting merit are centrally approved for negotiation and award by the ACT II Committee. The resulting contracts are awarded through various Army procurement offices and are jointly managed by BL project officers and technical experts in appropriate Army labs and RDECs.

In 1994, its inaugural year, ACT II funded a total of 28 projects. In 1995, 35 projects were selected for funding and have completed demonstrations and final reports. The 1996 ACT II Program is currently proceeding with 25 projects scheduled for execution in the current year. To date, 27 projects from 1994 and 1995 have been identified for further investigation, resulting in a Concept Exploration Program, integration into other current acquisition programs as product improvements, or inclusion in the Army's Warfighting Rapid Acquisition Program. ACT II funding was $20 million in FY94, $40 million in FY95, and $12.5 million in FY96; it is approximately $11 million for FY97.

ACT II is an ongoing program within the Army. An industry-focused Pre-Proposal Conference for the FY97 ACT II was held during April 1996. The Broad Agency Announcement for the FY97 cycle was released on 6 May 1996, with concept papers due to ARO by 31 May 1996. Full proposals were invited in early July 1996 and responses evaluated during August–September 1996. Contracts for the FY97 program should be signed during December 1996.

3. Army Efforts with Other DoD Agencies

Many Army S&T activities are coupled with programs of the other Services and with other Department of Defense agencies. The major agencies with which the Army interacts are the Defense Advanced Research Projects Agency (DARPA), the Defense Special Weapons Agency (DSWA), the Ballistic Missile Defense Organization (BMDO), and the U.S. Special Operations Command (USSOCOM). Working relationships between Army and agency technical staffs have included coordinated program planning, parallel funding, and, in some cases, joint agency/Army program management by Army S&T organizations.

a. Defense S&T Reliance

Defense S&T Reliance is based on a set of formal agreements among and implemented by participants in Department of Defense science and technology development.

Reliance today involves full membership for each Military Department, the Ballistic Missile Defense Organization, Defense Mapping Agency, Defense Advanced Research Projects Agency, and the Defense Special Weapons Agency. The Deputy Director of Defense for Research and Engineering (DDDR&E) is also an active participant in the Reliance process.

The goals and objectives of Defense S&T Reliance reflect the enduring challenges that face the Defense S&T Community. The goals of Defense S&T Reliance are to:

- Enhance the quality of Defense S&T activities.
- Ensure the existence of a critical mass of resources that will develop "world class" products.
- Reduce redundant S&T capabilities and eliminate unwarranted duplication.
- Gain productivity and efficiency through collocation and consolidation of in-house S&T work, when appropriate.
- Preserve the vital mission-essential capabilities of the Services throughout the process.

Reliance agreements involve joint planning, collocated in-house work, and lead Service/ Agency assignment. They encompass both in-house and related contract work.

The Reliance process obtains guidance from the Office of the Secretary of Defense (OSD) and OSD's policy formulation bodies. Strategic guidance from OSD, the Joint Chiefs of Staff (JCS) statements, warfighting requirements, and rationale required by the S&T community for it to define and implement an effective Defense S&T program.

b. The Defense Special Weapons Agency and Treaty Verification

The Services, the Defense Special Weapons Agency (DSWA), and the Department of Energy (DoE) weapons laboratories are involved in a long-term nuclear weapons effects (NWE) technology and test program. Major program elements include NWE research, NWE simulators, and (in the past) underground nuclear tests. The project is gathering essential data for effectively hardening those technologies that are incorporated in current and future military systems. Army laboratories and DSWA are also working jointly in the development of advanced simulation technology.

The Chemical Weapons (CW) Convention Treaty includes a provision for compliance monitoring via on-site inspection. DSWA is the DoD Executive Agent for RDT&E programs related to treaty verification and compliance, while the Army is the DoD Executive Agent for chemical and biological defense. Accordingly, the Army and DSWA have created a working environment, via a Memorandum of Agreement (MOA), in which the Army is the lead performer for sampling methodology and audit trails, chemical agent sensor assessments, sampling and protective devices and equipment, and field demonstrations of available technology. U.S. Army Edgewood Research, Development and Engineering Center is coordinating Army technology efforts in this area. The program is funded by DSWA. The MOA was signed in FY90, and detailed technical planning and implementation continues.

c. Defense Advanced Research Projects Agency

The Defense Advanced Research Projects Agency (DARPA) was founded in 1958 to foster innovative military research and development. It has a long history of close cooperation with the Army in pursuit of advanced technology for future battlefields. For instance, DARPA supported technological proof of principle for the Tank Breaker system that forms the basis for the Army's Javelin developmental fire-and-forget anti-tank missile. DARPA also conducted the Assault Breaker experiment, which linked smart munitions with advanced target acquisition radar. This deep attack system was developed by the Army and Air Force and was used successfully in Operation Desert Storm as the Army Tactical Missile System (ATACMS) and the Joint Surveillance and Target Attack Radar System (JSTARS).

DARPA works closely with the Army and other Service users to ensure that it prioritizes emerging technologies that will be of the most importance in meeting the nation's security needs. DARPA provides the Services with ready access to all the nation's research capabilities in industry, academia, and government research centers and laboratories for the solution of emerging military requirements.

One of the most important programs in which DARPA and the Army are currently cooperating is the Advanced Land Combat (ALC) technology program. A joint program office including the Army, Marine Corps, and DARPA has been set up at DARPA to develop the Hunter Vehicle component of the Rapid Force Projection Initiative under ALC. This program will integrate advanced materials and structures in an ultra-lightweight hull that can be readily transported by rotary- and fixed-wing aircraft to trouble spots anywhere in the world.

The Hunter Vehicle will demonstrate novel countermeasure techniques that are melded together with innovative high performance ballistic materials to defeat a range of threats. This effort will be performed in concert with survivability projects undertaken by the Army.

A critical component of these survivability activities will be a device to automatically identify friendly forces without relying on an exploitable signature of some kind. DARPA has been working closely with the Army in demonstrating a reliable near-term combat identification system, and is developing concepts and technologies for a longer-term system for future combat identification.

d. Ballistic Missile Defense Organization

The Strategic Defense Initiative Organization (SDIO), chartered in 1984 to manage the Department of Defense's efforts in ballistic missile defense, is now the Ballistic Missile Defense Organization (BMDO), which reports to the Under Secretary of Defense for Acquisition and Technology. While BMDO is the focal point for policy and program formulation, the operational aspects of BMD work are performed through the BMD Executive Agents and their research facilities, Service commands, and other installations at various locations throughout the United States.

A detailed description of U.S. Army Space and Strategic Defense Command (USASSDC) roles, responsibilities, and contributions with respect to BMD, the Army Space and Strategic Defense Program, and the Army S&T program is given in Volume II, Annex D.

e. U.S. Special Operations Command

The U.S. Special Operations Command (USSOCOM), established in 1987, unifies all continental-based special operations forces under a single commander. USSOCOM's unique responsibilities include the following missions: unconventional warfare, direct actions, special reconnaissance, foreign internal defense, counterterrorism, psychological operations, civil affairs, counterproliferation, and information warfare. Among these missions, USSOCOM was granted the authority to develop and acquire special operations-peculiar equipment, materiel, supplies, and services. In 1992, Congress recognized that USSOCOM R&D funding was inadequate to support the command's technology needs and directed that USSOCOM compete for other agencies' technology base development needs. USSOCOM's science and technology budget is principally technology demonstration (80 percent) with lower funding in technology development (20 percent).

A review by technology managers within the USSOCOM and the U.S. Army Special Operations Command (USASOC) headquarters staffs has shown that many Special Operations Forces (SOF) technology needs and requirements are being or can be addressed in Army laboratories and centers, and that the SOF community can maximize its return on investment by coupling with current and planned Army technology efforts. One example of the joint interaction of these R&D organizations is the 21st Century Land Warrior program. USSOCOM and USASOC have played active roles in the Army Materiel Command's Technology-Base Seminar War Games and have conducted intercommand seminars, exercises, and equipment expositions to improve their partnership with the Army R&D community. The SOF community also plays an active role in TRADOC's development of the Soldier, provides input into the Army Modernization Plan, and participates in the Army's Future Soldier System Tech Base Executive Steering Committee, the group that coordinates and determines the appropriate technologies for upgrading the soldier of the future. Annex F in Volume II of this ASTMP discusses USSOCOM's current technology program and technology requirements for improving their operational capabilities.

f. Scientific Services Program (SSP)

The Army Research Office (ARO) monitors this competitively awarded program which consists of six components:

- Short-Term Analysis Service (STAS).
- Laboratory Research Cooperative Program (LRCP).
- Conferences, Workshops, and Symposia.
- Summer Faculty Research and Engineering Program (SFREP).
- Summer Associateship Program for High School Science and Mathematics Faculty (HSSMF).
- Post Laboratory Research Cooperative Program/Post Summer Faculty Research and Engineering Program (PLRCP/PSFREP).

The STAS program is the largest component, processing between 200 and 300 projects annually, originating from all three Services and other government agencies. The objective of the STAS program is to competitively award short-term projects to academic or small business scientists who complement, but do not duplicate, government expertise. Awards are usually less than $100,000 each, less than a year's duration, and award is usually made within 30 days of receipt of the work order. The SFREP has become a popular program with about 150 faculty being placed at Army labs or centers each year. The total SSP annually awards about $10–15 million.

4. Army Efforts with Other Federal Agencies

The Army cooperates with many other federal agencies to accomplish missions of mutual interest, obtain access to unique capabilities not available within the Army, and provide other agencies access to unique Army capabilities. Major efforts with DoE and NASA allow the Army to leverage capabilities closely related to Army needs, which are supported by research budgets much larger than the Army's. Some efforts with DoE and NASA described below are large (millions of dollars per year) and are negotiated at the Under Secretary level, but many smaller efforts with these and other agencies are negotiated at the Laboratory level.

a. Activities with the National Aeronautics and Space Administration (NASA)

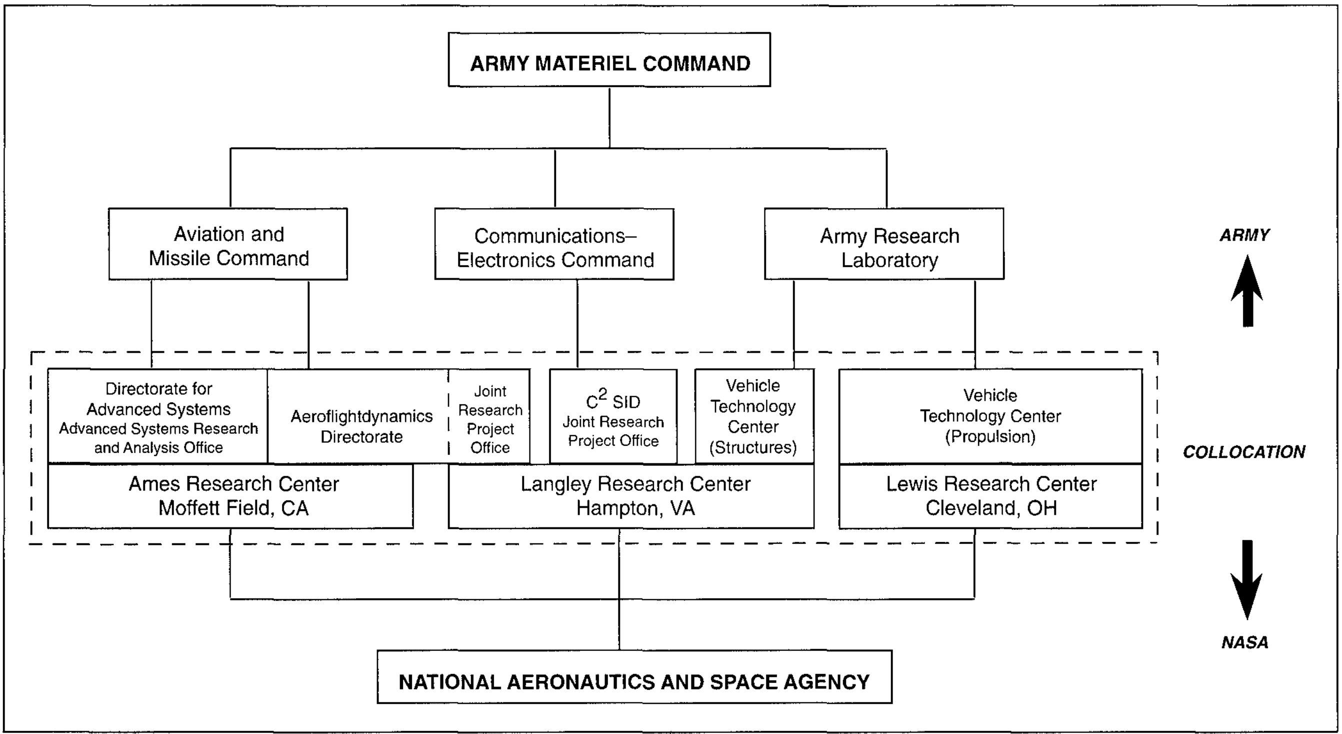
In 1965, the U.S. Army Materiel Command (AMC) and NASA signed an agreement for joint participation in aeronautical technology related to Army aviation. The original agreement issued to what is now the Army Aviation and Missile Command (AMCOM) an open-ended permit to use NASA's 7- by 10-foot Subsonic Wind tunnel located at NASA Ames Research Center. The original agreement has been expanded over the years to include the Army Research Laboratory (ARL) Vehicle Technology Center at NASA Langley and Lewis Research Centers (LaRC and LeRC, respectively) and two Joint Research Program Offices at LaRC. The agreement has evolved over the years to include elements of Army Research Laboratory, AMCOM, and Communications-Electronics Command (CECOM) as illustrated in Figure VII-7.

This cooperative arrangement allows Army engineers direct access to NASA's world-class research facilities. For example, the Army has access to facilities at the Ames Research Center alone worth more than $1 billion, with an annual operating cost of more than $60 million, but the Army directly incurs less than one percent of the annual cost.

Army scientific and engineering personnel may be assigned within the NASA organization but they work on programs of Army interest as negotiated by the Army director with their NASA Division or Branch Chiefs. This ensures that Army resources are focused on Army priorities and permits both the Army and NASA to accomplish more with less.

Since the agreement's inception, the Army and NASA have participated in joint research and development to their mutual benefit. Cooperative and integrated research efforts, shared resources, and close physical proximity have fostered the development of technologies in aeromechanics, human-machine integration, structures and materials, and propulsion. These joint efforts allow the Army and NASA to focus the national R&D effort in ground vehicle and rotorcraft technologies which allows the Army to spin off avia-

Figure VII-7. Army/NASA Joint Aeronautical Research Locations



tion technologies to its other missions such as ground vehicles, bridges, and missiles. Thirty years of Army/NASA cooperation has provided an opportunity for the Army to leverage NASA resources and programs and also to contribute to advancement of an integrated civil and military technology base.

This agreement, which makes dual-use technology development a reality, has become known simply as the Army/NASA Joint Agreement.

b. Activities with the Department of Energy

Army technical leaders maintain close ties with counterparts in the Department of Energy (DoE), both formally and informally, in order to leverage their multi-billion dollar annual RDTE investment. The Army taps DoE assets through both Army-funded reimbursable programs ("work for others" in DoE terminology), and through jointly funded programs (where strong mutual interest justifies DoE funding as well). Rapid evolution of the DoE Labs' missions will require restructuring of our cooperative efforts. New leverage opportunities will appear as capabilities once fully committed to DoE-funded projects become accessible to the Army, but others will disappear as capabilities once they are converted from defense to civilian applications, redirected, or closed out.

A cooperative effort at the Oak Ridge National Laboratory (ORNL) developed advanced robotics technology of interest to both parties, and also transferred Army-developed technology to DoE's environmental and waste management program. A very large number of Army-funded programs exploit unique capabilities at each of the National Labs. Some typical areas of endeavor at ORNL include: Materials for Reduced Weight and Advanced Armor (composites, ceramics, carbon/carbon boding, intermetallics, modeling of crack propagation, and advanced processing concepts); Advanced Instrumentation (sensors for robotics applications and detection of incoming threats, detection of chemical/biological agents using laser technology, and advanced automation); Environmental Assessment and Remediation (topography, bioremediation, chemical process technology, characterization of fuels and byproducts); and Electrical Power Systems (ultra-light small engine-generators as well as power systems for electric guns). Discussions are under way which may lead to research on environmentally friendly replacements for depleted uranium (DU) in penetrators and other applications. A similar long list of examples could be compiled for each of the large multi-program National Labs.

c. Cooperation with Drug and Law Enforcement Agencies (DLEAs)

In a memorandum dated 31 December 1990, the Assistant Secretary of the Army (ASA)(RDA) designated his Deputy for Combat Service Support to represent the Office of the ASA(RDA) with all non-DoD agencies, as well as with all DoD offices, agencies, and departments involved in counterdrug activities. The Assistant Secretary's memorandum also established the Army Counterdrug RDA Office.

The Army currently provides management oversight on 17 counterdrug programs. These programs encompass a variety of different technology areas, from non-intrusive inspection to a number of automation systems. The emphasis is on the transfer of dual use technologies from DoD to DLEAs and utilizing DoD expertise to assist the DLEAs.

One of the programs under the Army's purview is the Transcription/Translation Support System (T2S2). The T2S2 is an audio collection and recording system which supports Drug Enforcement Administration (DEA) Title III wire tap operations. T2S2 is a key backbone communications system that accelerates the prosecution of drug traffickers. The system provides near real-time collection, recording, and forwarding of digitized voice intercepts from Title III Wiretap Collection and Recording Sites located in New York City, Miami, Houston, and Los Angeles. The voice intercepts are forwarded to a Remote Processing Transcription/Translation Support Center located in Draper, UT, via dedicated long haul communications carriers. The system provides for the transfer of translated and transcripted text files from the Transcription/Translation Support Center back to the originating collection and recording sites. The transcripts are then used in court for the prosecution of drug traffickers. Initial Operating Capability occurred in the first quarter of FY96.

Diminishing resources and an escalating threat from drug traffickers resulted in the development of the Army's Counterdrug Technology Information Network (CTIN). CTIN builds on the premise that information and knowledge of available technologies can help bridge the gap between threat and resources. CTIN also capitalizes on technology as a force multiplier and allows the counterdrug community to achieve economies of scale via cooperative acquisitions. CTIN contains descriptions and points of contact for several hundred systems and techniques that may be of help in countering the illegal narcotics threat.

CTIN has two parts. The first part is a World Wide Web site that may be viewed by anyone. The Web site gives a description of CTIN, titles of systems described in CTIN, and instructions on how to apply for excess U.S. government equipment.

The second and main part of CTIN is an easy to use bulletin-board-like system (BBS) that is hidden from the general public. Using the BBS, you can read the wealth of information that is there and ask and answer questions with other users. The BBS can be accessed via modem or through the internet, using either a Mac or Windows PC. It requires that you be approved as a user by the U.S. Army Counterdrug RDA Office.

The CTIN supports the DoD and the Department of Justice (DoJ) Memorandum of Understanding (MOU) to identify existing DoD equipment, ongoing technology development programs that can be shared, and new military technology projects which solve problems common to the military and law enforcement communities. As part of that MOU, a Joint Program Steering Group (JPSG) was formed at the Defense Advanced Research Projects Agency. The DoD/DoJ relationship is based on common interest derived from emphasis on a traditional military mission called Operations Other Than War (OOTW). In general, law enforcement applications require technology and systems which will be affordable, safe to use on or around people with varying medical conditions, acceptable to the public, and consistent with the Constitutional rights of all involved. Some of the specific areas of interest include Concealed Weapons Detection; Less Than Lethal Technology; Tracking, Tagging, and Status Monitoring; Interactive Simulation and Training; Explosives Detection, Neutralization, and Disposal; Small Mobile Sensor Technology; Urban Mapping and Three Dimensional Scene Generation; Advanced Sensor Integration; Safe Gun Technology; Information Technology; Biomedical; Portable Power; Anti-Sniper; and Advanced Body Armor.

d. Cooperation with Other Agencies

Over a dozen years of joint research on robotics with the Department of Commerce's (DoC's) National Institute of Standards and Technology (NIST) have led to major success in the application of flexible computer architectures to DoD unmanned ground vehicle testbeds for hazardous military missions such as reconnaissance. This experience has allowed the Army and NIST to collaborate on civil programs, such as the Department of Transportation's Intelligent Vehicle Highway System. Such successful joint activities have led to an active effort to find additional areas for potential cooperation with NIST, including dual-use opportunities and opportunities for one party to take advantage of unique capabilities of the other.

As part of the Strategic Environmental Research and Development Program (SERDP), joint research is being conducted with EPA and DoE on a multitude of environmental topics. For example, a National Environmental Technology Test Site Program, managed jointly by the Army, Navy, and Air Force, has been developed to demonstrate, evaluate, and transfer innovative cleanup technologies from R&D to full-scale use. Another example is the partnering between the Army, other Services, DoE, and EPA for the development and fielding of a Site Characterization and Analysis Penetrometer System (SCAPS), a system used for site characterization in the DoD's cleanup program. Each organization has a defined area of responsibility, thereby maximizing use of limited funds for addressing common DoD cleanup problems. A joint program under SERDP has also been initiated with EPA and DoE in development of a groundwater modeling system for contaminated site cleanup.

The Army, as lead agency for DoD, is working with EPA on biodiversity research through a Biodiversity Research Consortium. Results of this cooperative effort will allow DoD to optimize its biodiversity research, thereby enhancing its capability to manage biodiversity on DoD sites in a bioregional and national context.

The Army cooperates on a smaller scale with a number of other U.S. Government agencies to accomplish a mutual goal or share a unique capability. These agencies include the Departments of Health and Human Services, Labor, and Education; the National Oceanic and Atmospheric Administration; the Food and Drug Administration; and the U.S. Geological Survey.

5. Army Efforts with Industry

a. National Automotive Center (NAC)

Recognizing the many dual use benefits to be exchanged among industry, academia, and government, the Army established the National Automotive Center in 1993. The NAC is located at the U.S. Army Tank-Automotive Research, Development and Engineering Center, Warren, Michigan, and serves to accelerate the development of dual use automotive technologies. Through the use of Broad Agency Announcements (BAAs), the NAC leverages commercial R&D projects which have potential military applications. In conjunction with the Department of the Army Domestic Technology Transfer Office, the NAC has developed a blanket Cooperative R&D Agreement (CRDA) between the Army and the major American car manufacturers—General Motors, Ford, and Chrysler. The NAC also interfaces with the United States Council for Automotive Research (USCAR) and automotive vendors, suppliers, and small businesses to identify areas of potential collaboration with the automotive industry. It also coordinates with other government agencies such as the Advanced Research Projects Agency and the Departments of Energy, Transportation, and Commerce, and is developing agreements with them for coordination of mutual automotive technology projects.

b. National Rotorcraft Technology Center (NRTC)

The NRTC, established in 1996, is a catalyst for facilitating collaborative rotorcraft research and development between the DoD (Army and Navy), the National Aeronautics and Space Administration (NASA), the Federal Aviation Administration (FAA), industry, and academia. It will serve as the means to cooperatively develop and implement a rotorcraft technology plan and national strategy that can effectively address both civil and military rotorcraft needs. The effort will establish an aggressive and clearly focused approach to ensure continued superiority of U.S. military rotorcraft while concurrently strengthening the U.S. rotorcraft industry's ability to compete in the global market.

The NRTC adds an innovative approach to include U.S. industry and academia as partners through their focal point, the Rotorcraft Industry Technology Association (RITA), a nonprofit corporation formed for this purpose. This partnership will focus on developing rotorcraft design, engineering and manufacturing technologies and sharing technology among RITA members. U.S. industry will have a proactive role in defining the technology tasks to be undertaken. Initial strategic thrusts of the NRTC will address the following five critical path civil/military rotorcraft issues: (a) critical dual-use technologies, (b) passenger and community acceptance, (c) product and process development, (d) aviation infrastructure, and (e) civil and military standards. Research project costs will be shared by government funding matched or exceeded by industry's participation. The government office of the NRTC is located in existing facilities at NASA Ames Research Center, Moffett Field, California.

E. The Federated Laboratory Concept—A New Paradigm

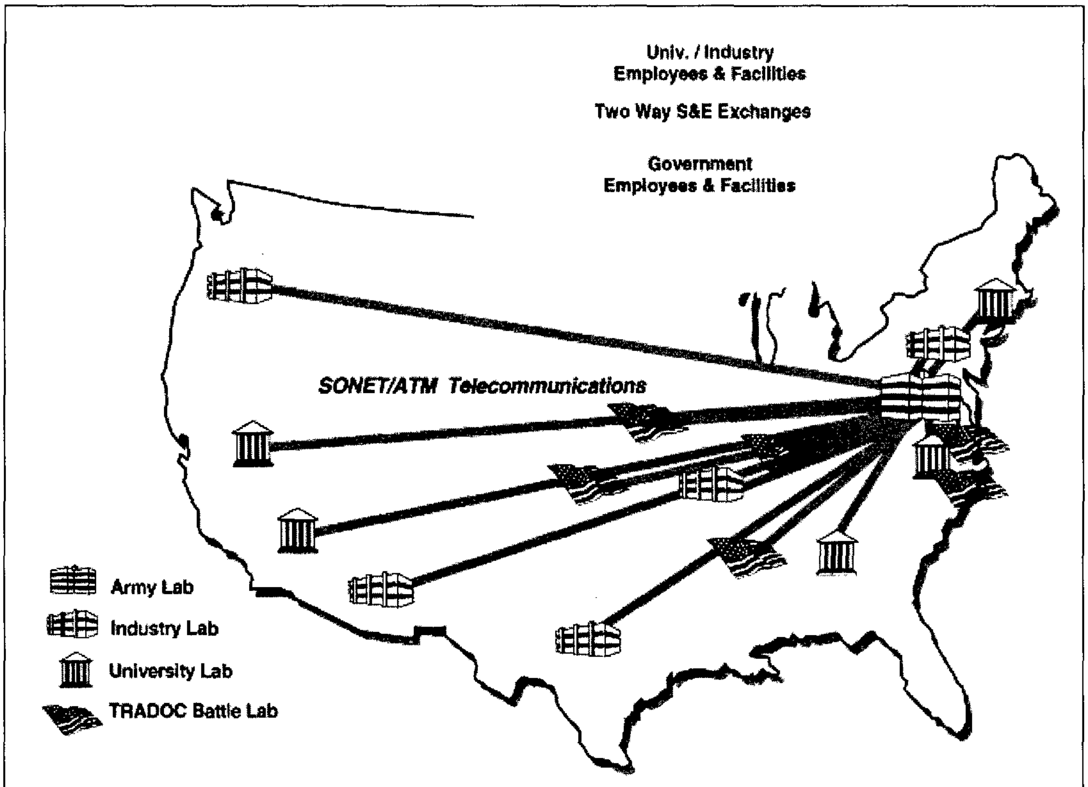
In many areas, such as information science, technology is advancing so fast that the Army cannot and should not lead, but must build on the Nation's civil infrastructure. The traditional short-term approach is to let a series of contracts to solve specific isolated problems. The new paradigm is to create a "federated laboratory," which forges long-term cooperative relationships with carefully selected partners. Work of these partners is integrated into a unified effort, including (when appropriate) inhouse work in specialized areas. Traditional hard boundaries between government, industry, and academia become more permeable as work and people move back and forth between partners.

The federated laboratory was conceived to meet the realities of the post-Cold War environment. Downsizing of Defense has resulted in excess capacity in government, industry, and university R&D sectors. This provides an opportunity to collaborate with external centers of technical expertise in new ways. The objective is to continue strong in-house effort to meet Army-unique requirements where there is little external expertise, but to forge direct associations with industry, university, and other government laboratories in areas where the centers of expertise are outside the Army. This cooperative mode also encourages dual use.

The Army Research Laboratory is serving as a prototype of this new approach. ARL will have two major "centers of gravity." At Aberdeen, Maryland, ARL will maintain a predominantly in-house program focused on armor, armament, and soldier systems. In these areas we have unique Army requirements and historically strong capabilities. At Adelphi, Maryland, ARL will develop a predominantly external program to "Win the Information War." As we strengthen our efforts in digital telecommunications, battlefield command and control, and information science, we will build on the world-class capabilities of some of our nation's best institutions, not create duplicate capability inhouse. As illustrated in Figure VII-8, we must develop an entirely new operational concept linking ARL, industry, academic institutions, and other government laboratories into a unified whole.

Efforts with an in-house center of gravity will use about 60 to 80 percent of their resources inhouse because of their recognized expertise and the uniqueness of their work. Under the new paradigm they will be more strongly linked to industry, academia, and other government laboratories to gain leverage through open lab programs and personnel exchanges. Efforts with an external center of gravity will use about 60 to 80 percent of their resources externally. The inhouse portion will maintain a core competency and smart-buyer role. Here the emphasis will be on multi-center external modes of operation with substantial personnel exchanges among partners.

Figure VII-8. Distributed Capabilities in Army Laboratories, Industry, Academia, and TRADOC Battle Labs



F. International Technology Leveraging

1. Rationale/Policy

In the light of the realities of shrinking defense budgets in the post-Cold War era and coalition approach to resolving international conflicts, participation in international cooperative R&D in key technology areas such as those described in this section is becoming increasingly important. These efforts offer high payoff opportunities for leveraging U.S. investments in technology development with those of our international partners and help build the political relationships that are required for coalition operations. Such leverage will help maintain U.S. technological advantage, stimulate battlefield interoperability, and, through subsequent co-development of advanced dual-use technology products, sustain our economic competitiveness. Cooperative R&D offers the U.S. Army a means of remaining oriented to future and next generation needs and continuing to learn about new ideas and new approaches.

Secretary of Defense Perry, in his policy memorandum of 25 June 1993, calls for a renaissance in armaments cooperation:

As we address issues of defense reinvestment and as our armed forces and those of our allies draw down, it is critical that we look for every opportunity to increase the effectiveness of those forces while making the most efficient use of the resources we apply to our collective defenses. I believe that armaments cooperation can be a primary means of achieving those ends. Our objectives in armaments cooperation must include the following:

- *Deployment and support of common, or at least interoperable, equipment with our allies.*
- *Leverage of our resources through cost sharing and economies of scale afforded by coordinated research, development, production, and logistics support programs.*

- *Exploitation of the best technologies, military or civilian, available for the equipping of alliance forces.*

In the sections that follow, the discussion covers the mechanisms for international cooperation, specific technology leveraging opportunities, and future trends. The specific technology leveraging opportunities are designed in coordination with Chapter 4 and in conjunction with Annex E of Volume II to provide the researcher with enough information and connectivity to allow facilitated access to allied technology.

2. Army International Organizations

a. The Deputy Under Secretary of the Army for International Affairs (DUSA[IA])

The Army has taken several steps to streamline Army International Cooperative Programs toward achieving the goals elaborated by Secretary of Defense Perry with the formation of the DUSA(IA). On May 15, 1996, the DUSA(IA) was formed to integrate, coordinate, and focus all Army international activities to include regional assessments, policy integration, security assistance, international cooperation, and resource management activities. All policy functions from SARDA, DCSOPS, DALO, and AMC were brought together. This consolidation provides the Army with a more unified coordinated international policy and approach for international activities from operations to requirements, to materiel development, to international standardization and Multinational Force Compatibility (MFC).

The DUSA(IA) draws the line between policy and execution; the DUSA(IA) develops and promulgates policy with AMC and TRADOC executing that policy. AMC will continue to oversee the development and execution of International Agreements (IAs) for materiel development to feed MFC. TRADOC will manage the development of coalition doctrine through such forums as Army to Army Staff Talks and international programs such as the Battlefield Interoperability Program (BIP), while continuing the development and execution of International Standardization Agreements—all designed to promote MFC that will enable the Army to fight two Regional Conflicts at one time.

b. The U.S. Army Materiel Command, International Cooperative Programs Activity

To enable AMC to execute international agreements in support of materiel development, HQDA "chartered," i.e., empowered AMC, to develop and execute IAs (Information/Data Exchange Agreements, Scientist and Engineer Exchanges, and Technical Research and Development Project Agreements) for AMC-managed technology. This is done under HQDA (DUSA[IA]) policy, whereby 21 days' silence is consent in order to execute.

A new approach to staffing international agreements is now being promulgated to the field activities in the form of Integrated Product Teams (IPTs). This approach to product development, which will now be used to staff international agreements, calls on key individuals involved in a process to bring their skills and expertise to bear as a team. With the Army's new "single voice approach" through the DUSA(IA), the empowerment of TRADOC and AMC to approve and execute international programs, and the IPT process, the staffing and disposition of international agreements will be significantly streamlined.

3. International Cooperation

The Army's strategic goal in international cooperation is to promote basic strategy of technology leveraging. Leveraging refers to activities that multiply the effects of U.S. investment in technology by taking advantage of the investments and capabilities of others.

Programs can range from cooperation in basic science and technology, through co-development and foreign weapons testing and evaluation, to co-production, foreign sales, and downstream logistics support. Most international programs are focused on exploratory development and the earliest stages of advanced development. We also support small research ("seed") contracts with world-class researchers and maintain research offices in London and Tokyo.

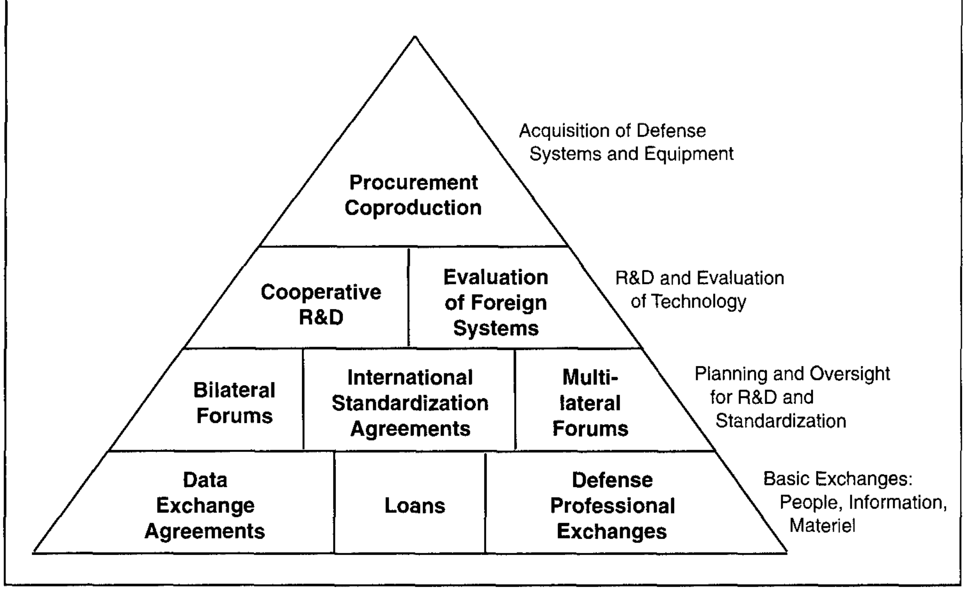
Our strategy encourages partnering with our allies to ensure that our programs incorporate and reflect the best available technology worldwide. Leveraging the technology investments that we make with those made by our allies eliminates duplication of effort and ensures the best technology at the lowest cost to the Army. We use a combination of techniques and methods that are shown as the building blocks of international cooperation in Figure VII-9.

The foundation of international cooperation is the exchange of information (or data), loans of materiel, and the exchange of defense professionals, primarily scientists and engineers (S&Es). This is the fundamental level of cooperation—the base of the triangle. Information and data are exchanged under the Defense Data Exchange Program, in which the Army actively participates in individual data or information exchanges with more than 25 countries in more than 250 technologies. The Army also exchanges defense professionals with allies to work on-site on common technical problems and opportunities. These exchanges occur formally, through the International Professional (S&E) Exchange Program and the short-term Abbreviated Professional Exchange Program (APEX), and informally, through visits and interactions at technical symposia, conferences, and meetings.

At the next level, international cooperation is facilitated by science and technology forums (bilateral and multilateral) which foster and coordinate international cooperative activities. Three such forums are the bilateral Technology Working Groups (TWGs) with Israel and France, and "home-on-home" visits with the United Kingdom (UK). Other activities at this level include the multilateral forums of The Technology Cooperation Program (TTCP), whose members include Australia, Canada, New Zealand, the United Kingdom, and the United States; and the NATO Defense Research Groups and Standardization Groups. Such forums provide management oversight and direction to individual technical experts participating in international exchange programs.

International cooperation at a level beyond simple information exchange (such as exchanges of equipment and laboratory samples, or co-development of hardware and software) generally occurs through cooperative research and development (R&D) programs. Cooperative R&D is executed under a Memorandum of Agreement (MOA), which spells out terms, conditions, and commitments of the United States and the partner country in pursuing agreed-to R&D objectives. A recently implemented variation of the traditional focused MOU agreement is the Technology Research and Development Program (TRDP), which is also known as an umbrella MOA. This type of MOA, which has been implemented with the United Kingdom, France, Germany, and Canada, allows for project annexes in specific areas of R&D cooperation and reduces the need and time required for renegotiating common elements of all MOAs (e.g., intellectual property rights) with a given ally.

Figure VII-9. Building Blocks of International Cooperation



In an effort to leverage all domestic and international resources, Army agencies are now joining with other U.S. Government agencies to pool their talents and resources on high-payoff cooperative R&D projects where there are common interests and requirements. One such program is the U.S. India Fund run by the Department of State. This program is designed to promote basic research with Indian universities and government facilities. Another, better-known program is the NATO Cooperative R&D Program, now expanded to include other major non-NATO allies—Korea, Japan, Israel, Egypt, and Australia. This program is also known as the Nunn program after the original amendment to the FY86 DoD Authorization Act, sponsored by Senator Sam Nunn.

Proposed Nunn-funded projects address key Army technologies (both conventional Army defense and dual-use) that respond to areas of significant interest to our Allies and where a joint approach (with our Allies) is critical. Funding for these projects, of course, remains dependent on the DoD-wide approval and agreement process.

The Foreign Comparative Test Program provides funding to determine whether foreign systems satisfy U.S. Army requirements. Finally, our strategy for international cooperation includes co-production and procurement of systems with the ultimate goal of standardization and interoperability of equipment.

4. Opportunities

The Army assesses international opportunities across a broad spectrum of subject areas on a continuing basis. Subjects addressed in recent studies include artificial intelligence, anti-armor technology, autonomous guidance, microelectronics, computing and simulation, aerospace propulsion, biotechnology, virtual reality, photonics, robotic sensors, materials and structures, and military power sources.

Leveraging opportunities have also been identified through several other mechanisms:

- Individual scientists and engineers (S&Es) recommendations based on their direct experience with foreign S&Es.
- International working groups of test engineers, working in a program for 11 years developing over 70 test procedures that incorporate the best work of all countries.
- Comparison of selected ASTMP milestones with ally S&T documents.

Table VII-1 highlights the breadth of leveraging opportunities discussed in greater depth in Annex E. This table also provides a crosswalk between the basic research topics (defined in Chapter 5) and technologies (defined in Chapter 4). The arrows indicate a rough qualitative assessment of those areas where the individual tables contained in Annex E identify a critical mass of foreign basic and applied research capabilities. The numerous overlaps evident in the crosswalk are indicative of a growing depth of infrastructure combining where both basic and applied efforts offer potential for long-term, sustained cooperation. Finally, the arrows give a qualitative feel for the quality of the research capability and key trends as shown in the legend to the table.

Accessing foreign technology in compliance with legal and security requirements through cooperative programs requires international agreements. These legal vehicles may allow the bench S&Es access to foreign technology covered by the scope of such agreements to address near- and mid-term requirements. Volume II, Annex E, of the ASTMP further describes technology leveraging opportunities while providing Army points of contact through which further details can be obtained. Figure VII-10 illustrates how these technology leveraging opportunities could impact major Army systems.

5. Army Digitization Program

Digitization of the battlefield has emerged as a major thrust of U.S. national military planning. The Army Digitization Master Plan calls for the development of systems to achieve a tactical inter-networked C3I system that will significantly enhance situation awareness, force integration, combat identification and target hand-off, database distribution, and communications. The International Digitization Strategy provides the framework for international cooperation to enhance interoperability and technology leveraging. In the mid and far terms, international programs will enhance capabilities with reduced technical risk by ensuring the Army access to advanced technologies and alternative approaches.

Worldwide technology trends and specific C4I technology leveraging opportunities have been

Table VII-1. International Opportunities Summary

TECHNOLOGY AREAS	BASIC RESEARCH AREAS											
	Mathematical Sciences	Computer and Information Systems	Physics	Chemistry	Materials Science	Electronics	Mechanical Sciences	Atmospheric Sciences	Terrestrial Sciences	Medical	Biological Sciences	Behavioral, Cogn and Neural Sc
Aerospace Propulsion and Power	➤			➤	➤		▲					
Air and Space Vehicles	➤		▲	➤	➤	▲	▲					▲
Nuclear, Biological and Chemical Defense				➤						▲	▲	
Individual Survivability and Sustainability				➤	▲					▲	▲	▲
Command, Control and Communications		▲				▲						▲
Computing and Software			▲									▲
Conventional Weapons				➤	➤		▲					
Electronic Devices			▲		➤	▲						
Electronic Warfare/ Directed Energy Weapons												
Civil Engineering and Environmental Quality			▲		➤						▲	
Battlespace Environments			▲			➤		➤	➤			
Human Systems Interfaces		▲										▲
Manpower, Personnel, and Training												▲
Materials, Processes, and Structures				➤	➤		▲				▲	
Medicial and Biomedical Science and Technology										▲	▲	
Sensors			▲		➤			➤	➤			
Ground Vehicles				➤	➤	➤	▲					
Manufacturing Science and Technology					▲		▲				▲	
Modeling and Simulation												▲

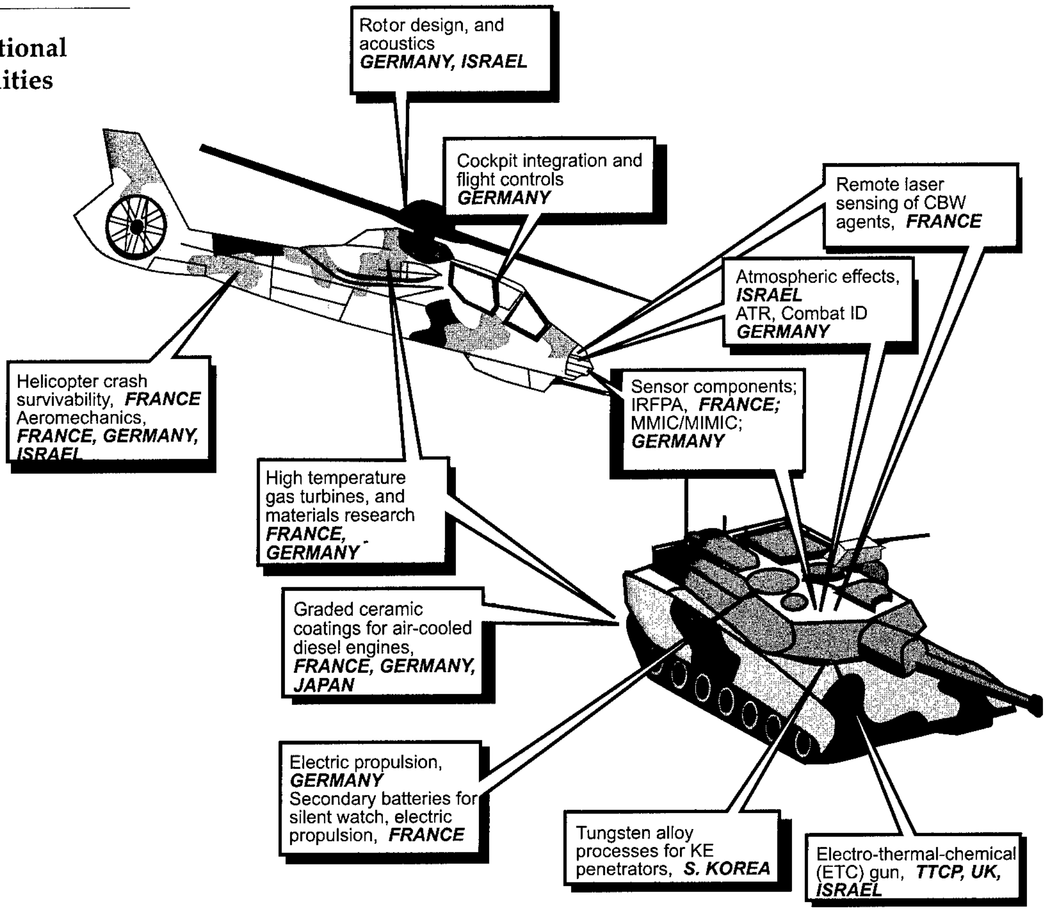
▲ One or more candidate countries identified have *capabilities with breadth and depth in application and basic research* key to ASTMP objectives, at a level likely to contribute to significant breakthroughs in the state of the art.

One or more candidate countries identified have capabilities in specific aspects of application or basic research key to ASTMP objectives, that could contribute to future breakthroughs in the state of the art.

➤ One or more candidate countries identified have capabilities with breadth and depth in application and basic research key to ASTMP objectives, at a level likely to contribute to the continued evolutionary advance of the state of the art.

One or more candidate countries identified have capabilities in specific aspects of application or basic research key to ASTMP objectives, that could contribute to the continued evolutionary advance of the state of the art.

Figure VII-10. International Cooperative Opportunities



identified in the Army Digitization Master Plan, Chapter 5, and the International Digitization Strategy. The strategy to leverage these opportunities is to focus on the following:

- Identifying critical information and communications technology opportunities through worldwide technology assessments
  - Advanced displays and interactive displays, particularly enhanced human interfaces to support improved operator effectiveness
  - Software and intelligent systems, particularly in language understanding/ translation and intelligent agents, process sensed and stored data and interact seamlessly with human operators and autonomous systems
  - Telecommunications and information distribution with emphasis on wireless digital data limits to provide secure, robust, real-time interchange of data between graphically dispersed and highly mobile force elements
  - Advanced distributed simulation of synthetic environments and automated forces and operations to allow distributed modeling and rehearsal of better conditions to support mission planning and force optimization
  - Advanced sensors, particularly multi-domain smart sensors for continuous, rapid, and precise discrimination and targeting of all threats under all anticipated battlefield conditions
- Encouraging industry-to-industry/academia teaming arrangements that allow the leveraging of allied commercial research and technology in identified critical technologies
- Utilizing existing agreements and forums when possible to exchange research and technology information and to develop specific new initiatives

The Army Research Laboratory's Federated Laboratory will provide new dynamic avenues for government-to-government relationships with enhanced opportunities for technology leveraging through industry-to-industry and academia-to-academia teaming arrangements.

Table VII-1 and Annex E have been expanded significantly in this revision of the ASTMP. Many of the added items apply directly to battlefield digitization. Figure VII-11 highlights opportunities identified in Annex E that directly support digitization.

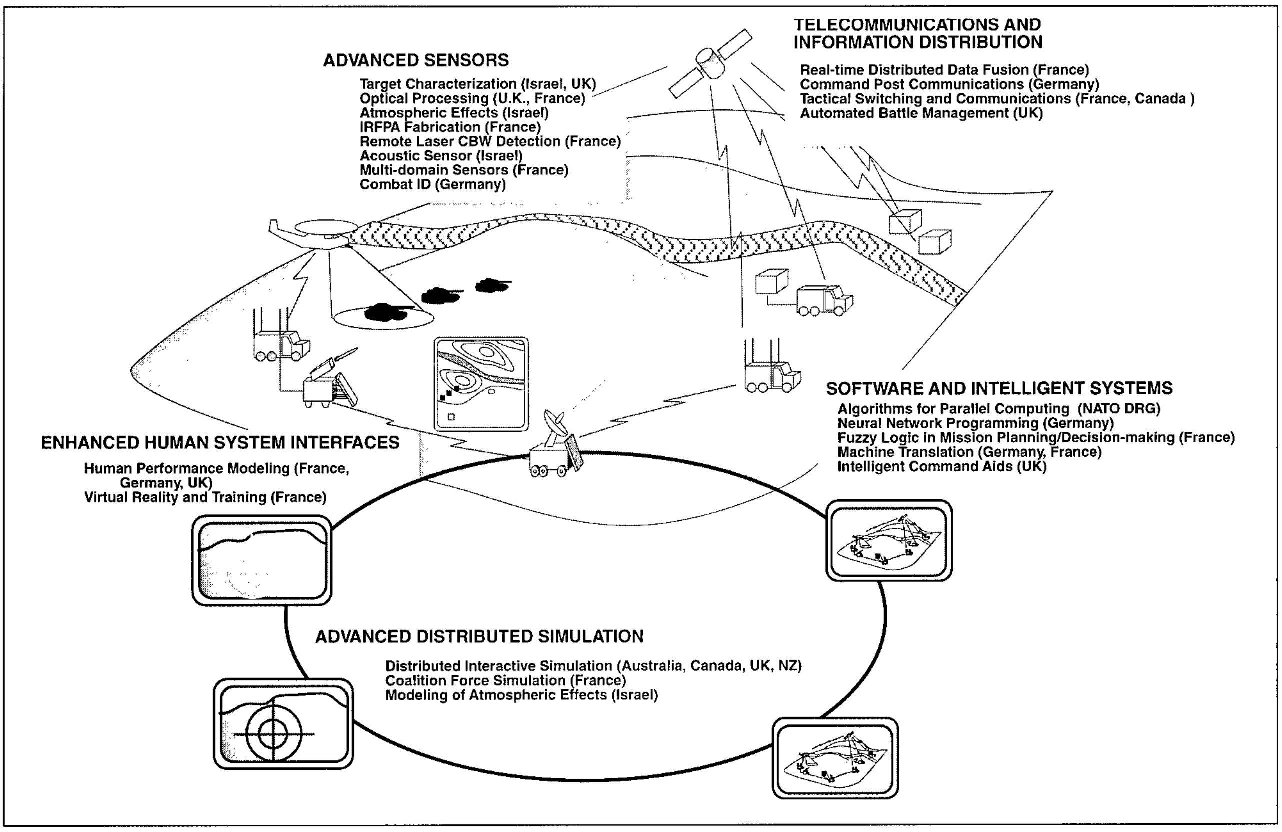
6. Future Trends

In an ever changing world, technology is a valuable global commodity. As discussed in the previous sections, access to technology to support Army programs is complementary to the mid- and far-term ASTMP milestones. The current trends assessment summarized in Table VII-1 and discussed in detail in Annex E (Figure E-2) shows that there are world-class capabilities in virtually all of the ASTMP research and technology areas (Chapters 4 and 5) outside the U.S. borders. The European Community will continue to provide significant capability in most of the Army's research and technology areas of interest. Similar trends are shown for Japan and to a lesser degree for Canada, Israel, and Sweden. A more limited contribution is indicated for other allies and the Former Soviet Union.

7. Summary

The benefits of international cooperation are well known and documented. Some are highly concrete, e.g., significant savings in time and cost. Others—improved interoperability, acquisition of information helpful to U.S. programs, and greater opportunity for contacts with researchers with new ideas and approaches to problems—are less quantifiable but no less valuable. With the formation of the DUSA(IA) for policy development and the empowering of HQAMC to execute international agreements, the Army has taken a major stride toward unifying and simplifying working with our allies. Given our shrinking resources, it is more important than ever to leverage research and technology if we are to maintain our qualitative edge over potential adversaries in the future.

Figure VII-11. International Opportunities Offer Broad Support for the Digitization Technology Base



G.

Summary

Establishing good Army interfaces with the outside—through partnerships, cost-sharing arrangements, and reliance on other organizations—is vital for enhancing the Army science and technology program and for strengthening and improving the Army's warfighting capabilities. Outreach programs also help lay the groundwork for the Army's future by cultivating important sources of new staff. These efforts forge relations outside the Army that contribute to fulfilling its military mission and to strengthening our civilian economy.

Appendix

Glossary

GLOSSARY

2-D	Two-Dimensional (length/width)
3-D	Three-Dimensional (length/width/height)
3rd GARD	3rd Generation Advanced Rotors Demonstration
4-D	Four-Dimensional (length/width/height/time)
A&P	Airfields and Pavements
A/D	Analog/Digital
A2	Antiarmor
A2C2	Army Airborne Command and Control System
A3I	Army–NASA Aircrew/Aircraft Integration
AAC	Army Acquisition Corps
AAE	Army Acquisition Executive
AAH	Advanced Attack Helicopter
AAMP	Army Aviation Modernization Plan
AAN	Army After Next
AAPS	Advanced Antenna Prototype Subsystem
ABCA	America, Britain, Canada, Australia
ABCS	Army Battle Command Systems
ACAP	Advanced Composite Aircraft Program
ACAT	Acquisition Category
ACE	ARM Countermeasures Evaluator
ACES	Arrow Continuation Experiments
ACISD	Advanced Computational and Information Science Directorate
ACOM	Atlantic Command
ACR	Advanced Concepts and Requirements
ACT	Advanced Cargo Transport; Active Control Technology
ACT II	Advanced Concepts and Technology Program II
ACTD	Advanced Concept Technology Demonstration
ACTFAST	Advanced Concepts and Technology Frequency Agile Solid State Tuner
ACTS	Advanced Communications Technology Satellite
ADA	Air Defense Artillery
ADAS	Air Deployable Acoustic Sensor
ADDEOS	Air Defense Electro-Optical System
ADO	Army Digitization Office

ADOCS	Advanced Digital Optical Control System
ADS	Advanced Distributed Simulation; Azimuth Determining System; Atmospheric Density Specification Satellite
ADTE	Advanced Technology Demonstrator Engine
ADTT	Army Domestic Technology Transfer
ADVOX	Advanced Oxidation Processes
AEI	Armament Enhancement Initiative
AERCAP	Artillery Extended Range Cargo Projectile
AF	Air Force
AFAS	Advanced Field Artillery System
AFDD	Aero Flight Dynamics Division
AFGWC	Air Force Global Weather Central
AFSOC	Air Force Special Operations Command
AGCCS	Army Global Command and Control System
AGES	Air/Ground Engagement Simulation
AGL	Above Ground Level
AGS	Armored Gun System
AH	Automated Howitzer
AHP	Advanced Helicopter Pilotage
AHPCRC	Army High Performance Computing Research Center
AI	Artificial Intelligence
AI2	Advanced Image Intensification
AIMS	Advanced Integrated Manportable System
AIN	Army Interoperability Network
AIPSYS	Advanced Integrated Pilotage System
AIR/OCEA EE	Air/Ocean Equipment Engineering
AIR/OCEA TA	Air/Ocean Tactical Applications
AIS	Autonomous Intelligent Submunition
ALBE	AirLand Battlefield Environment
ALBM	AirLand Battle Management
ALC	Advanced Land Combat; Adelphi Laboratory Center
ALERT	Air/Land Enhanced Reconnaissance and Targeting
ALIAS	Advanced Lightweight Intelligent Armament System
AlON	Aluminum Oxynitride
ALRPG	Army Long-Range Planning Guidance
AMC	Army Materiel Command; Army Medical Command
AMCOM	Aviation and Missile Command
AMP	Army Modernization Plan
AMRAAM	Advanced Medium Range Air-to-Air Missile
AMS	Advanced Mobility System
AMS-H	Advanced Missile Systems-Heavy
AMSGOSC	Army Model and Simulation General Officer Steering Committee
AMSO	Army Model and Simulation Office
AMTEC	Alkali Metal Thermal Electric Converters

ANM	Automated Network Management
AOA	Angle of Attack
AOR	Area of Responsibility
APG	Aberdeen Proving Ground
APS	Alternate Propulsion Sources; Active Protection Systems
APU	Auxillary Power Unit
ARC	Advanced Research Center; Advanced Rotor Concepts
ARDEC	Armaments Research, Development, and Engineering Center
ARI	Army Research Institute for the Behavioral and Social Sciences
ARL	Army Research Laboratory
ARM	Anti-Radiation Missile
ARO	Army Research Office
ARSS	Army Space Support Team
ART	Advanced Rotorcraft Transmission
ARTI	Advanced Rotorcraft Technology Integration
ARTY	Artillery
AS	Australia
ASA(RDA)	Assistant Secretary of the Army for Research, Development and Acquisition
ASAS	All Source Analysis System
ASB	Army Science Board
ASBREM	Armed Services Biomedical Research and Evaluation Management
ASCO	Advanced Systems and Concepts Office
ASE	Aircraft Survivability Equipment
ASHPC	Advanced Simulation and High Performance Computing
ASM	Armored Systems Modernization
ASRT	Autonomous Scout Rotorcraft Testbed
ASSH	Aircraft Systems Self-Healing
ASSERT	Augmentation Awards for Science and Engineering Training
ASST	Advanced Submunition Sensor Technology
ASTAG	Army Science and Technology Advisory Group
ASTIS	Army Software Technology Investment Strategy
ASTMIS	Army Science and Technology Management Information System
ASTMP	Army Science and Technology Master Plan
ASTWG	Army Science and Technology Working Group
ASW	Anti-Submarine Warfare
ATA/ATG	Air-to-Air/Air-to-Ground
ATACMS	Army Tactical Missile System
ATAS	Air-to-Air Stinger
ATCAS	Advanced Towed Cannon System
ATCAT	Advanced Rotorcraft Aeromechanics Technologies
ATCCS	Army Tactical Command and Control System
ATD	Advanced Technology Demonstration
ATG/GTG	Air-to-Ground, Ground-to-Ground (Rocket Technology)
ATGM	Anti-Tank Guided Missile

ATGW	Anti-Tank Guided Weapons
ATIRCM	Advanced Threat Infrared Countermeasures
ATM	Asynchronous Transfer Mode; Asynchronous Transfer Mechanism
ATOC	Air Defense/TMD Operation Center
ATR	Automatic Target Recognition/Recognizer
ATRJ	Advanced Threat Radar Jammer
ATT	Advanced Tank Technologies
AVCATT	Aviation Combined Arms Tactical Trainer
AVN	Aviation
AVRDEC	Aviation Research, Development and Engineering Center
AVT	Advanced Vehicle Technologies
AVTOC	Aviation Tactical Operations Center
AW	Air Warrior
AWE	Advanced Warfighting Experiment
AWG	Advanced Waveform Generator
AWIP	Advanced Weapons Integration Program
AWS	Air Weather Service
B	Billions
B&P	Bid and Proposal
B2C2	Battalion and Below Command and Control
BAA	Broad Agency Announcement
BADD	Battlefield Awareness and Data Dissemination
BAS	Battlefield Automated System
BAST	National Research Council's Board on Army Science and Technology
BAT	Brilliant Anti-Tank
BC	Battle Command
BC2	Battlespace Command and Control
BCDSS	Battle Command Decision Support System
BCID	Battlefield Combat Identification
BCIS	Battlefield Combat Identification System
BCNS	Behavioral, Cognitive, and Neural Sciences
BCTP	Battle Command Training Program
BD	Bird Dog; Battlefield Digitization
BDA	Battle Damage Assessment
BDS-D	Battlefield Distributed Simulation–Developmental
BE	Brilliant Eyes
BE2	Battlefield Environmental Effects
BEST	Battlespace Enhanced Survivability Technology
BFA	Battlefield Functional Area
BFM	Battlescale Forecast Model
BIDS	Biological Integrated Detection System
BIP	Battlefield Imaging Projectile
BIS	Battlespace Information System

B-ISDN	Broadband Integrated Services Digital Network
BIT/BITE	Built-In Test/Built-In Test Equipment
BITS	Battlefield Information Transmission System
BL	Battle Lab
BLIR-B	Boundary Layer Illumination and Radiance-Balance
BLOS	Beyond Line of Sight
BLWE	Battle Lab Warfighting Experiments
BM	Battle Management
BMAR	Backlog of Maintenance and Repair
BMC	Battlefield Manufacturing Center
BMDO	Ballistic Missile Defense Organization
BOA	Battlefield Ordnance Awareness
BOS	Battlefield Operating System
BRAC	Base Realignment and Closure
BRP	Basic Research Plan
BSFV	Bradley-Stinger Fighting Vehicle
BSM	Battlefield Spectrum Management
BTA	Best Technical Approach
BW	Biological Warfare; Bandwidth
C-C	Carbon-Carbon Composite
C&S	Casualty and Survivability
C2	Command and Control
C2E	Command Center Element
C2SID	Command and Control Systems Integration Dirctorate
C2T2	Commercial Communications Technology Testbed
C2V	Command and Control Vehicle
C2W	Command and Control Warfare
C3	Command, Control, and Communications
C3I	Command, Control, Communications, and Intelligence
C3IEW	Command, Control, Communications, Intelligence, and Electronic Warfare
C4	Command, Control, Communications, and Computers
C4I	Command, Control, Communications, Computers, and Intelligence
CA	Canada
CAA	Concepts Analysis Agency
CAAD	Corps Area Air Defense
CAAM	Computer Assisted Artillery Meteorology
CAC2	Combined Arms Command and Control
CAD	Computer-Aided Design
CAE	Computer-Aided Engineering
CAM	Computer-Aided Manufacturing
CAPS	Counter Active Protection Systems
CARC	Chemical Agent Resistant Coating
CARD	Catalog of Approved Requirements Documents

CASE	Computer-Aided Software Engineering
CATS	Combined Arms Training Strategy
CATT	Combined Arms Tactical Trainer
CAV	Composite Armored Vehicle
CAV-ATD	Composite Armored Vehicle - Advanced Technology Demonstration
CB	Chemical/Biological
CBD	Chemical/Biological Defense
CBW	Chemical/Biological Warfare
CCAWS	Close Combat Anti-Armor Weapon System
CCD	Camouflage, Concealment, and Deception
CCL	Close Combat Light
CCTDE	Compound Cycle Turbine–Diesel Engine
CCTT	Close Combat Tactical Trainer
CD	Counterdrug
CDA	Commander's Decision Aid
CDFS II	Cloud Depiction and Forecast System II
CECOM	Communications-Electronics Command (U.S. Army)
CELP	Code Excited Linear Predictive
CEP	Circular Error Projection
CERDEC	Communications–Electronics Research, Development and Engineering Center
CERL	Construction Engineering Research Laboratory
CERT	Center of Excellence for Research in Training
CFD	Computational Fluid Dynamics
CG	Commanding General
CGF	Computer-Generated Forces
CGS	Common Ground Station
CHPR	Cooper-Harper Pilot's Rating
CHS	Common Hardware/Software; Combat Health Support
CI	Counterintelligence
CID	Combat Identification
CIDS	Combat Identification for the Dismounted Soldier
CIMMD	Close-In Manportable Mine Detector
CINC	Commander-in-Chief
CINCIPL	Commanders in Chief Integrated Priority List
CINCUSFK	CINC U.S. Forces Korea
CITV	Commander's Independent Thermal Viewer
CKEM	Compact Kinetic Energy Missile
CLASS	Closed Loop Artillery Simulation System
CM	Countermeasures; Cruise Missile; Countermine
CMC/CC	Ceramic Matrix Composites/Carbon Composites
CMOS	Complementary Metal Oxide Semiconductor
CMTC	Combat Maneuver Training Center
CNI	Communication, Navigation, Identification

CNR	Combat Net Radio
COE	Center of Excellence; Common Operating Environment
COMINT	Communications Intelligence
COMSEC	Communications Security
CONOPS	Continuous Operations
CONSCAN	Conical Scan
CONUS	Continental United States
Corps SAM	Corps Surface-to-Air Missile
COTS	Commercial Off-the-Shelf
CP	Counterproliferation; Collective Protection
CPAR	Construction Productivity Advancement Research
CR	Cold Regions
CRDA	Cooperative Research and Development Agreement
CRREL	Cold Regions Research and Engineering Laboratory
CS	Combat Support
CSIP	Crew Systems Integration and Protection
CSSCS	Combat Service Support Control System
CS/TMBS	Crew Station/Turret Motion Base Simulator
CSOPA	Combat Systems Oceanographic Performance Assessment
CSRDF	Crew-Station Research and Development Facility
CSS	Combat Services Support
CTC	Combat Training Center
CTIN	Counterdrug Technology Information Network
CTIS	Combat Terrain Information System
CUNY	City University of New York
CVCC	Combat Vehicle Command and Control
CVD	Chemical Vapor Deposition
CVM	Computational Vision Model
CVSD	Continuously Variable Slope Delta
CW	Chemical Warfare
CWS	Combat Weather System
DA	Department of the Army
DAMA	Demand Assignment Multiple Access
DARO	Defense Airborne Reconnaissance Office
DARPA	Defense Advanced Research Projects Agency
DAS	Director of Army Staff
DAS(R&T)	Deputy Assistant Secretary for Research and Technology
DBBL	Dismounted Battlespace Battle Lab
DBC	Digital Battlefield Communications
DBS	Dismounted Battle Space
DCP	Dynamic Cone Penetrometer
DCSCD	Deputy Chief of Staff for Combat Developments
DCSINT	Deputy Chief of Staff for Intelligence

DCSLOG	Deputy Chief of Staff for Logistics
DCSOPS	Deputy Chief of Staff for Operations and Plans
DCSPER	Deputy Chief of Staff for Personnel
DCST	Deputy Chief of Staff for Training
DDR&E	Director, Defense Research and Engineering
DDS	Direct Digital Synthesizer
DE	Directed Energy
DEA	Data Exchange Agreement; Drug Enforcement Agency
DEC	Digital Equipment Corporation
DEMIL	Demilitarization
DEM/VAL	Demonstration and Validation
DENS	Directed Energy Neutralization System
DEPSCOR	Defense Experimental Program to Simulate Competitive Research
DET	Dynamic Environment and Terrain
DEW	Directed Energy Weapon
DF	Direction Finder
DIS	Distributed Interactive Simulation
DISA	Defense Information Systems Agency
DISC4	Director, Information Systems, Command, Control, Communications, and Computers
DISGOSC	Distributed Interactive Simulation General Officer Steering Committee
DLEAs	Drug and Law Enforcement Agencies
DLMP	Doctrine Literature Master Plan
DMA	Defense Mapping Agency
DMSO	Defense Modeling and Simulation Office
DMSP	Defense Meteorological Satellite Program
DNA	Defense Nuclear Agency; Deoxyribonucleic Acid
D/NAPS	Day/Night Adverse Weather Pilotage System
DoC	Department of Commerce
DOCC	Deep Operations Coordination Cell
DoD	Department of Defense
DoE	Department of Energy
DOE	Diffractive Optical Elements
DOF	Degrees of Freedom
DoJ	Department of Justice
DOP	Depth of Penetration
DP	Defense Program
DPG	Defense Planning Guidance
DPICM	Dual Purpose Improved Conventional Munition
DRAM	Dynamic RAM
DRE	Ducted Rocket Engine
DREN	Defense Research and Engineering Network
DRFM	Digital Radio Frequency Memory
DSA	Depth and Simultaneous Attack

DSB	Defense Science Board
DSCS	Defense Satellite Communications System
DSI	Defense Simulation Internet
DSP	Digital Signal Processor
DSSA	Domain Specific Software Architecture
DSTAG	Defense S&T Advisory Group
DSTWG	Defense Science and Technology Working Group
DSWA	Defense Special Weapons Agency
DT	Development Test
DTAP	Defense Technology Area Plan
DTB	Defense Technology Board
DTD	Digital Terrain Data
DTED	Digital Terrain Elevation Data
DTIC	Defense Technology Information Center
DTLOMS	Doctrine, Training, Leader Development, Organization, Materiel, and Soldiers
DTO	Defense Technology Objective
DTSS	Digital Topographic Support System
DU	Depleted Uranium
DURIP	Defense University Research Program
DUSA-IA	Deputy Undersecretary of the Army for International Affairs
DUSA-OR	Deputy Undersecretary of the Army-Operations Research
DUSD/AT	Deputy Undersecretary of Defense for Advanced Technology
DUWL	Dual Use Wireless LAN
EA	Electronic Attack
EAD	Echelon Above Division
EARC	Electric Armaments Research Center
EBF	Electronic Battlefield
ECC	Experiment Control Center
ECCM	Electronic Counter-Countermeasures
ECM	Electronic Countermeasures
ECOG	Electronics Coordinating Group
ECP	Engineering Change Proposal
EELS	Early Entry, Lethality, and Survivability
EFG	Edge-Defined Film Fed Growth
EFOGM	Enhanced Fiber-Optic Guided Missile
EFP	Explosively Formed Penetrator
EHF	Extremely High Frequency
E-Gun	Electric Gun
EISS-AD	Electronic Integrated Sensor Suite for Air Defense
ELINT	Electronic Intelligence
EM	Electromagnetic
EMD	Engineering and Manufacturing Development

EME	Electromagnetic Environment
EMI	Electromagnetic Interference
EMP	Electromagnetic Pulse
EMUT	Enhanced Manpack UHF Terminals
EMW	Engineer and Mine Warfare
ENCATT	Engineer Combined Arms Tactical Trainer
ENG	Engineer
EO or E-O	Electro-Optic
EO/IR	Electro-Optical/Infrared
EOCM	Electro-Optical Countermeasure
EPA	Environmental Protection Agency; Extended Planning Annex
EPLRS	Enhanced Position Location Reporting System
ER	Extended Range
ERA	Extended Range Artillery
ERDEC	Edgewood Research, Development, and Engineering Center
ERINT	Extended Range Interceptor
ES	Electronic Support
ESM	Electronic Support Measures
ESS	Electrostatic Sensor
ETC	Electrothermal Chemical
EUT	Early User Test
EW	Electronic Warfare
EWIRCM	Electronic Warfare Infrared Countermeasure
EXCAP	Simulation of National Sensors
FAA	Federal Aviation Administration
FAAD	Forward Area Air Defense
FAAPS	Field Artillery Ammo Processing System
FACE	Forward Aviation Combat Engineering
FAMSIM	Family of Simulations
FARP	Forward Arm and Refuel Point
Farret	A Cruise-Type Missile
FARV	Future Armored Resupply Vehicle
FAST	Field Assistance in Science and Technology; Forward Area Support Terminal
FBCB2	Force XXI Battle Command Brigade and Below
FCR	Fire Control Radar
FCS	Fire Control System; Future Combat System
FDA	Food and Drug Administration
FDDI	Fiber Distributed Data Interface
FDDM	Fire Direction Data Manager
FDR	Future Digital Radio
FDS/ADS	Fixed Distributed System/Advanced Deployable System
FET	Field Effect Transistors

FFRDC	Federally Funded Research and Development Center
FI/LTL	Flame Incendiary/Less Than Lethal
FIV	Future Infantry Vehicle
FLIR	Forward Looking Infrared
FLITE	Flying Laboratory for Integrated Testing and Evaluation
FLOT	Forward Line of Troops
FM	Field Manual; Frequency Modulation
FMBT	Future Main Battle Tank
FMTI	Future Missile Technology Integration
FMTV	Family of Medium Tactical Vehicles
FNMOC	Fleet Numerical Meteorological and Oceanography Center
FOC	Future Operational Capability
FO/FAC	Forward Observer/Forward Air Controller
FOG	Fiber-Optic Gyro
FOG-M	Fiber-Optic Guided Missile
FoM	Figure of Merit
FOPEN	Foliage Penetration
FOR	Family of Operational Rations; Field-of-Regard
FORSCOM	Forces Command
FOTLAN	Fiber Optic Tactical LAN
FOV	Field of View
FPA	Focal Plane Array
FR	France
FRI	Focused Research Initiative
FSCS	Future Scout and Cavalry System
FSP	Full Scale Production
FSV	Future Scout Vehicle
FT	Future Tank
FTW	Future Technology Workshop
FY	Fiscal Year
FXXI	Force XXI
FYDP	Future Years Defense Plan
G&C	Guidance and Control
GaAs	Gallium Arsenide
GASCO	Generic Algorithm for Cockpit Optimization
GBCS	Ground-Based Common Sensor
GBI	Ground-Based Interceptor
GBR	Ground-Based Radar
GCCS	Global Command and Control
GCI	Ground Control Intercept
GE	Germany
GEN II	Generation II
GFLOPS	Giga (Billions) of Floating Point Operations per Second

GIF	Guidance Integrated Fuze
GIS	Geographic Information Systems
GOPS	Giga Operations Per Second
GOSC	General Office Steering Committee
GOTS	Government Off-the-Shelf
GPADS	Guided Parafoil Air Delivery System
GPAL	Global Protection Against Limited Strikes
GPEN	Ground Penetration
GPRA	Government Performance and Results Act
GPS	Global Positioning System
GRASS	Geographic Resources Analysis Support System
GRCS	Guardrail Common Sensor
GSM/CGS	Ground Station Module/Common Ground Station
GTWAPS	Global Tactical Weather Analysis and Prediction System
GVW	Gross Vehicle Weight
HACT	Helicopter Active Control Technology
HAZTOX	Hazardous and Toxic
HBCU/MI	Historically Black Colleges and Universities/Minority Institutions
HCTR	High Capacity Trunk Radio
HDTV	High Density Television
HE	High Explosive
HEEDS	Hardness Enhancement and Evaluation of Detector Subarrays
HELSTF	High Energy Laser Systems Test Facility
HF	High Frequency
HF/VHF	High Frequency/Very High Frequency
HICAP	High Capacity Artillery Projectile
HIMARS	High Mobility Artillery Rocket System
HITL	Hardware in the Loop (Simulation)
HITRAN	High Altitude Atmospheric Transmission
HIV	Human Immunodeficiency Virus
HLA	High Level Architecture
HMD	Helmet-Mounted Display
HMGL	High Mobility Ground-Launched
HMMS	Helmet-Mounted-Mobility Sensor
HMMWV	High Mobility, Multipurpose Wheeled Vehicle
HMPT	Human Factors, Manpower, Personnel, and Training
HMVS	Helmet-Mounted Vision System
HPC	High Performance Computing
HPM	High Power Microwave
HPRF	High Power Radio Frequency
HRDS	High Resolution Display System
HRED	Human Research and Engineering Directorate of the Army Research Laboratory

HSD	Hypertonic Saline Dextran
HSI	Hyperspectral Imagery; Human-System Interfaces
HSS	Health Service Support
HSSMF	High School Science and Mathematics Faculty
HTI	Horizontal Technology Integration
HTSC	High Temperature Super Conductor
HUMINT	Human Intelligence
HV	Hunter Vehicle
HVAC	Heating, Ventilating, and Air Conditioning
HVM	Hypervelocity Missile
HVW	Hypervelocity Weapon
HWIL	Hardware-in-the-Loop
I/O	Input/Output
I2	Image Intensification
I2R	Imaging Infrared
IAS	Integrated Acoustic System
IAT	Institute for Advanced Technology
IBAD	Ion Beam Assisted Deposition
IC	Integrated Circuit
ICASE	Integrated CASE
ICH	Improved Cargo Helicopter
ICM	Improved Conventional Munitions
ICT	Integrated Concept Team
ID	Identification
IDT	Integrated Devices Technology (a company name)
IEC	Integration and Evaluation Center
IEW	Intelligence and Electronic Warfare
IEWCS	Intelligence and Electronic Warfare Countermeasures Suite
IFF	Identification Friend or Foe
IFFC	Integrated Fire and Flight Control
IFMMS	Integrated Facility Maintenance Management System
IFOG	Interferometric Fiber-Optic Gyro
IFSAR	Interferometric Synthetic Aperture Radar
IHFR	Improved High Frequency Radio
IHPTET	Integrated High Performance Turbine Engine Technology
IHS	Integrated Headgear System
ILIR	In-House Laboratory Independent Research
ILMS	Improved Launcher Mechanical Systems
ILSP	Integrated Logistics Support Plan
IM&D	Information Management and Display
IMETS	Integrated Meteorological System
IMF	Intelligent Mine Field
IMINT	Imagery Intelligence

IMO	International Mathematical Olympiad
IMPRINT	Integrated MANPRINT Tools
IMU	International Measurements Unit; Inertial Measurement Unit
INFOSEC	Information Security
IO	Information Operations
IOC	Initial Operational Capability
IP	Internet Protocol
IP ATM	Internet Protocol Asynchronous Transfer Mode
IPB	Intelligence Preparation of the Battlefield
IPE	Integrated Platform Electronics
IPPD	Integrated Process and Product Development
IPS	Interface and Power Subsystem
IR	Infrared
IRCM	Infrared Countermeasure
IR&D	Independent Research and Development
IRFPA	Infrared Focal Plane Array
IRST	IR Search and Track
IS	Israel; Integrated Sight
ISACM	Integrated Situational Awareness and Countermeasures
IS&T	Information Science and Technology
ISC	Information Systems Command
ISC/R	Individual Soldier's Computer/Radio
ISDN	Integrated Services Digital Network
ISEF	International Science and Engineering Fair
ISEMS	Improved Spectrum Efficiency Modeling and Simulation
ISM	Integrated Sight Module
ISO	International Standardization Organization
ISTD	Information Sciences and Technology Directorate
ISYSCON	Integrated System Control
ITD	Interim Terrain Data
IVIS	Intervehicular Information System/Radio Interface Unit
JA	Japan
JACK	3-D human figure model for CAD use
JASON	A group of scientific advisors to the government
JBPDS	Joint Biological Point Detection System
JBREWS	Joint Biological Remote Early Warning System
JBSDS	Joint Biological Standoff Detection System
JCAD	Joint Chemical Agent Detector
JCS	Joint Chiefs of Staff
JDL	Joint Directors of Laboratories
JFKSWCS	J. F. Kennedy Special Warfare Center and School
JPO-BD	Joint Project Office - Biological Detection
JPS	Joint Precision Strike

JPSD	Joint Precision Strike Demonstration
JPSG	Joint Program Steering Group
JRPO	Joint Research Project Office
JRTC	Joint Readiness Training Center
JSAM	Joint Service Aviation Mask
JSAWM	Joint Service Agent Water Monitor
JSCMAD	Joint Service Chemical Miniature Agent Detector
JSEP	Job Skills Education Program
JSGPM	Joint Service General Purpose Mask
JSHS	Junior Science and Humanities Symposium
JSPP	Joint Service Program Plan
JSSAMP	Joint Service Small Arms Master Plan
JSTARS	Joint Surveillance Target Attack Radar System
JSWILD	Joint Service Warning and Identification LIDAR Detector
JTACS	Joint Tactical Area Communications System
JTAGG	Joint Turbine Advanced Gas Generator
JTAGS	Joint Tactical Ground Station
JTF	Joint Task Force
JTR	Joint Transport Rotorcraft
JWARN	Joint Warning and Reporting Network
JWCA	Joint Warfighting Capabilities Assessment
JWCO	Joint Warfighting Capability Objective
JWID	Joint Warfighter Interoperability Demonstration
JWSTP	Joint Warfighting Science and Technology Plan
KE	Kinetic Energy
KEM	Kinetic Energy Missile
KEW	Kinetic Energy Weapon
km	Kilometer
KMR	Kwajalein Missile Range
KS	South Korea
L/D	Lift/Drag Ratio
L/V	Lethality/Vulnerability
LAD	Log Anchor Desk
LADAR	Laser Radar
LAH	Lightweight Automated Howitzer
LAM	Louisiana Maneuvers
LAN	Local Area Network
LARC	NASA Langley Research Center
lbs	Pounds
LCATS	Low Cost Advanced Target Sensor
LCCM	Low Cost Competent Munition
LCD/LTL	Low Collated Damage/Less Than Lethal

LCG	Low Cost Guidance
LCLO	Low Cost Low Observable
LCMS	Laser Countermeasures System
LCPK	Low Cost Precision Kill
LCSEC	Life Cycle Software Enginering Center
LDS	Lexington Discrimination System
LeRC	NASA Lewis Research Center
LFSAR	Low Frequency Synthetic Aperture Radar
LH	Light Helicopter
Li	Lithium
LIC	Low Intensity Conflict
LIDAR	Light Detection and Ranging
LIF	Laser Induced Fluorescence
LO	Low Observable
LOBL	Lock-On-Before-Launch
LOG REARM	Logistics Rearm - Aviation
LongFOG	Long Range Fiber Optic Guided Missile
LOS	Line of Sight
LOSAT	Line of Sight Anti-Tank
LOWTRAN	Low Altitude Atmospheric Transmission
LOTS	Logistics Over-the-Shore
LPC	Linear Predictive Coding
LPI	Low Probability of Intercept
LQI	Laboratory Quality Initiative
LR	Long Range
LRCP	Laboratory Research Cooperative Program
LRF	Laser Rangefinder
LRIP	Low Rate Initial Production
LS	Line Scanner
LSCAD	Lightweight Standoff Chemical Agent Detector
LTL	Less Than Lethal
L/V	Lethality/Vulnerability
LW	Land Warrior
LWIR	Long Wave Infrared
m	Meter
M&R	Maintenance and Repair
M&S	Modeling and Simulation
MA	Multichambered Autoinjector
MACOM	Major Command
MANPRINT	Manpower and Personnel Integration
MARSS	Maintenance and Repair Support System
MAST	Marine Atmosphere Science and Technology
MASTER	Manufacturing and Structuring Technology for Efficient Rotorcraft

MAT	Multimode Airframe Technology
MATES	Manufacturing and Tooling Expert Systems
MBDRP	Medical Biological Defense Research Program
MBMMR	Multiband Multimode Radio
MC&G	Mapping, Charting, and Geodesy
MCC	Microclimate Cooling
MCM	Mine Countermeasures
MCS	Maneuver Control System
MCT	MOS Controlled Thyristers
MDHC	McDonnell-Douglas Helicopter Company
MECOG	Mechanics Coordinating Group
MELIOS	Mini Eye-Safe Laser IR Observation Set
MEM	Microelectromechanics
MEP	Mobile Electric Power; Mission Equipment Package
MERC	Mobility Enhancing Ration Components
METT-T	Mission, Enemy, Troops, Terrain, and Time
MFC	Multinational Force Compatibility
MFLS3	Multiple Folded Laser Surveillance Survivability Sensor
MFO	Multinational Force and Observers
MFOM	MLRS Family of Munitions/Submunitions
MFORCE	Master Forces (Army)
MFS3	Multifunction Staring Sensor Suite
MGR	Moving Target Indicator Ground Radar
MHE	Materials Handling Equipment
MICOM	Missile Command
MIDAS	Man-Machine Integration Design and Analysis System
MIHKEM	Miniature Hypervelocity Kinetic Energy Missile
MILES	Multiple Integrated Laser Engagement Simulation
MILSATCOM	Military Satellite CMILSTAR
MILSTAR	Military Strategic Tactical Relay
MILT	Military Language Tutor
min	Minute
MIRACL	Mid-Infrared Advanced Chemical Laser
MIS	Management Information System
MITL	Man-in-the-Loop
MJ	Megajoules
MLRS	Multiple Launch Rocket System
MLS	Multilevel Secure
mm	Millimeter
MMADS	Molecular Modeling and Display System
MMC	Metal Matrix Composite
MMIC	Monolithic Microwave Integrated Circuit
MMIS	Military-Man-in-Space
MMS	Minerals Management Service; Mobile Measurement Set

MMUAV	Multi-Mission Unmanned Air Vehicle
MMW	Millimeter Wave
MNS	Mission Need Statement
MOA	Memorandum of Agreement
MOBA	Military Operations in Built-Up Areas
MOCVD	Metallo-Organic Chemical Vapor Deposition
ModSAF	Modular Semi-Automated Forces
MOFA	Multi-Option Fuze for Artillery
MOMBE	Metallo-Organic Molecular Beam Epitaxy
MOP	Measure of Performance
MOPP	Mission Oriented Protective Posture
MOS	Metal Oxide Semiconductors; Military Occupational Specialty
MOSART	Moderate Spectral Atmospheric Radiance and Transmittance
MOU	Memorandum of Understanding
MOUT	Military Operations in Urban Terrain
MP&S	Materials, Processes, and Structures
mph	Miles Per Hour
MPIM	Multi-Purpose Individual Munition
MPIM/P	Multi-Purpose Individual Munition/Predator
MPL	Multi Platform Launcher
MPM	Microwave Power Module; Medium Power Microwave
MPP	Massively Parallel Processing
MPT	Manpower, Personnel, and Training
MRDEC	Missile Research, Development and Engineering Center
MRE	Meals, Ready to Eat
MRL	Multiple Rocket Launcher
MRMAAV	Multirole Mission Adaptable Air Vehicle
MRMC	Medical Research and Materiel Command
MRSR	Multi-Role Survivable Radar
MS	Multispectral; Milestone; Mass Spectroscopy
MS&T	Manufacturing Science and Technology
MSAT	Multi-Sensor Aided Targeting—Air
MSC	Major Subordinate Command
MSCM	Multispectral Countermeasures
MSE	Mobile Subscriber Equipment
MSEG&C	Multi-Spectral Environmental Generator and Chamber
MSF	Mobile Strike Force
MSIP	Multi-Stage Improvement Program
MSLS3	Multiple Folded Laser Surveillance Survivability Sensor
MSTAR	MLRS Smart Tactical Rocket
MT	Masked Targeting
MTBF	Mean Time Before Failure
MTD	Mounted Battle Space
MTEDS	MCM Tactical Environmental Data System

MTI	Moving Target Indicator
MTTR	Mean Time to Repair
MURI	Multidisciplinary University Research Initiative
MW	Mounted Warrior
NAAS	Nerve Agent Antidote System
NAC	National Automotive Center
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAVOCEANO	Naval Oceanographic Office
NBC	Nuclear, Biological, and Chemical
NCTR	Non-Cooperative Target Recognition
NDE	Non-Destructive Evaluation/Inspection
NDI	Non-Developmental Item
NDSEG	National Defense Science and Engineering Graduate Fellowship Program
NE	Noise Equivalent
NEOF	No Evidence of Failure
NIH	National Institutes of Health
NII	National Information Infrastructure
NIR	Near Infrared
N-ISDN	Narrowband Integrated Services Digital Network
NIST	National Institute of Standards and Technology
NMD	National Missile Defense
NMRI	Naval Medical Research Institute
NMS	National Military Strategy
NOAA	National Oceanic and Atmospheric Administration
NOE	Nap-of-the-Earth
NP	Nonproliferation
NRC	National Research Council
NRDEC	Natick Research, Development, and Engineering Center (SSCOM)
NRTC	National Rotorcraft Training Center
NSA	National Security Agency
NSC	National Science Center
NSF	National Science Foundation
NSTC	National Science and Technology Council
NSTD	Non-System Training Devices
NTC	National Training Center
NTDR	Near-Term Digital Radio
NTM	National Technical Means
NTR	National Transport Rotorcraft
NVESD	Night Vision/Electronic Sensors Directorate
NWE	Nuclear Weapons Effects
NWP	Numerical Weather Prediction

O&S	Operations and Support
OASA(RDA)	Office of the Assistant Secretary of the Army (Research, Development and Acquisition)
OASYS	Obstacle Avoidance System
OBIDS	On-Board Integrated Diagnostics Systems
OCONUS	Outside the Continental United States
OCR	Operational Capability Requirement
OCSW	Objective Crew-Served Weapon
ODES	Operational and Deployment Experiments Simulator
ODS	Operation Desert Shield/Storm; Ozone Depleting Substances
OICW	Objective Individual Combat Weapon
OLTC	Open-Loop Tracking Complex
OMC	Organic (polymer) Matrix Composite
ONS	Operational Need Statement
OOTW	Operations Other Than War
OPARS	Optimum Path Aircraft Routing System
OPDW	Objective Personal Defense Weapon
OPFOR	Opposing Forces
OPO	Optical Parametric Oscillator
OPSEC	Operational Security
OPTD	Operational Prognostics Technology Demonstration
OPTEC	Operational Test and Evaluation Command
OPW	Objective Personal Weapon
ORD	Operational Requirements Document
ORNL	Oak Ridge National Laboratory
ORSMC	Off-Route Smart Mine Clearance
ORTA	Office of Research and Technology Applications
OSC	Objective Supply Capability
OSD	Office of the Secretary of Defense
OSO	Operational Support Office
OSS	Optical Surveillance System
OT&E	Operational Test and Evaluation
OTM	On the Move
OTSR	Optimum Track Ship Routing
P3I	Preplanned Product Improvement
PAC-3	Patriot Advanced Capability-3
PA&E	Program Analysis and Evaluation
PAM	Pulse Amplitude Modulation; Penetration Augmented Munition
PASI	Power and Inertia Simulator
PBG	Program Budget Guidance
PCR	Polymerase Chain Reaction
PCS	Permanent Change of Station; Personal Communication System
PDF	Probability Density Function

PEO	Program Executive Office (Officer)
PGMM	Precision Guided Mortar Munition
PIP	Product Improvement Program
PLA	Patent License Agreement
PLD	Pulsed Laser Deposition
PLEXUS	Phillips Lab Expert-Assisted User Software
PLRCP	Post Laboratory Research Cooperative Program
PM	Program Manager
PM-ACIS	Program Manager - Aircrew Integrated Systems (formerly PM-ALSE)
PM-ALSE	Program Manager - Aviation Life Support Equipment
PMBS	Pintle Motion Base Simulator
PNGV	Partnership for New Generation Vehicles
POM	Program Objective Memorandum
POS/NAV	Position/Navigation
PPBES	Planning, Programming, Budgeting, and Execution System
PPVS	Personnel Protection Validation System
PQA	Petroleum Quality Analysis
PR/WNA	Packet Radio/Wireless Network Access
PS	Protective Subsystem
PSA	Pressure Swing Absorption
PSFREP	Post Summer Faculty Research and Engineering Program
PSM	Personnel Status Monitor
PSS	Passive Sensor System
PSYOPS	Psychological Operations
PW	Prairie Warrior
QRMP	Quick Response Multicolor Printer
R&D	Research and Development
RACE	Rotorcraft Air Combat Enhancement
RAM	Random Access Memory; Reliability, Availability, Maintainability
RAMDA	Repair and Maintenance of Damaged Aircraft
RAP	Radio Access Point
RASCAL	Rotocraft/Aircrew Systems Concepts Airborne Laboratory
RASP	Robust Airframe Structures Program
RASS	Radio Acoustic Sounding System
RASTR	Real Aperture Stationary Target Radar
RBV	Rapid Battlefield Visualization
RBV–ACTD	Rapid Battlefield Visualization–Advanced Concept Technology Demonstration
RC	Reserve Component
RCRA	Resource Conservation and Recovery Act
RCS	Radar Cross Section
RD&J	Radar Deception and Jamming

RDA	Research, Development and Acquisition
RDEC	Research, Development and Engineering Center
RDT&E	Research, Development, Test and Evaluation
REAP	Research and Engineering Apprenticeship Program
RF	Radio Frequency
RF/IR/Laser	Radio Frequency/Infrared/Laser
RFCM	Radio Frequency Countermeasures
RFDEW	Radio Frequency Directed Energy Warfare
RFPI	Rapid Force Projection Initiative
RIMS	R&D Information Management System
RISTA	Reconnaissance, Intelligence, Surveillance, Target Acquisition
RITA	Rotorcraft Industry Technology Association
RNA	Ribonucleic Acid
rnds	Rounds
ROBS	Rapid Optical Beam Steering System
ROWS	Remote Observing Weather Sensor
RP	Red Phosphorus
RPA	Rotorcraft Pilot's Associate
RPI	Rensselaer Polytechnic Institute
RPV	Remotely Piloted Vehicle
RSOP	Reconnaissance, Selection, and Operation of Position
RSTA	Reconnaissance/Surveillance/Target Acquisition
RTM	Resin Transfer Molding; Requirements Translation Model
RTSP	Reactive Topical Skin Protectant
RV	Remote Vehicle
RWR	Radar Warning Receivers
RWST	Rotary-Wing Structure Technology
RWV	Rotary Wing Vehicle
S&Es	Scientists and Engineers
S&PS	Survivability and Protective Structure
S&T	Science and Technology
S&TF	Systems and Technology Forum
S/SU/AC	Systems/Systems Upgrades and Advanced Concepts
SA	Situation Awareness
SADARM	Sense and Destroy Armor
SAFOR	Semi-Automated Forces
SAM	Surface-to-Air Missile
SAMAS	Structure and Manpower Allocation System
SAMP	Small Arms Master Plan
SAR	Synthetic Aperture Radar
SARAP	Survivable, Affordable, Repairable Airframe Program
SARDA	Office of the Assistant Secretary of the Army (Research, Development and Acquisition)

SAS	Survivable Adaptive System
SATCOM	Satellite Communications
SBG	Spiral-Bevel Gear
SBIR	Small Business Innovation Research
SCAMP	Single-Channel Anti-Jam Manportable
SCAPP	Standardized Camouflage Paint Pattern
SCAPS	Site Characterization and Analysis Penetrometer System
SCAS	Stability Control Augmentation System
SCDMS	Structural Crash Dynamics
SCIP	Systems Integration and Protection
SD	Self-defense
SDIO	Strategic Defense Initiative Organization
SDW	Semi-rigid Deployable Wing
SEAP	Science and Engineering Apprentice Program
SEB	Staphylococcal Enterotoxin B
sec	Second
SED	Software Engineering Directorate
SEM-E	Standard Electronic Module Format-E
SEP	System Enhancement Program; Synthetic Environment Program; Soldier Enhancement Program
SER	System Evolution Record
SERA	Sequential Electrochemical Reduction Analysis
SERDP	Strategic Environmental Research and Development Program
SES	Senior Executive Service
SF	Special Forces
SFP	Sensor Fusion Processor
SFREP	Summer Faculty Research and Engineering Program
SHF	Super High Frequency
SHGR	Self-Heating Group Ration
SHIM	Self-Heating Individual Meal
SHTU	Simplified Hand Held Terminal Unit
SiC	Silicon Carbide
SICP	Single Integrated Command Post
Si-DLC	Silicon-Diamond Like Carbon Coating
SIGINT	Signals Intelligence
SIGS(NTM)	Synthetic Image Generator System (National Technical Means)
SII	Soldier Information Interface
SIMITAR	Simulation in Training for Advanced Readiness
SIMTECH	Simulation Technology
SINCGARS	Single Channel Ground and Airborne Radio System
SIPE	Soldier Integrated Protective Ensemble
SIRDAP	Science and Infrastructure Research, Development, and Acquisition Plan
SLAIR	Survivability/Lethality Advanced Integration in Rotorcraft
SLBD	Sea Lite Beam Director

SLCD	Small Lightweight Chemical Detector
SMART	Sensor Mounted as Roving Thread
SMI	Soldier-Machine Interface
SOA	Special Operations Aircraft
SOCOM	Special Operations Command
SOF	Special Operations Forces
SOF-PARS	Special Operations Forces-Planning and Rehearsal System
SONET	Synchronous Optical Network
SPG	Scientific Planning Group
SPIRITS	Spectral In-Band Radiometric Imaging of Targets and Scenes
sq mi	Square Miles
SR	Short Range
SRAW	Short-Range Antitank Weapon
SRO	Strategic Research Objective
SSCOM	Soldier Systems Command
SSDC	Space and Strategic Defense Command
SSES	Suite of Survivability Enhancements Team
SSGM	Synthetic Scene Generator Model
SSM/T2	Special Sensor Microwave/Temperature and Humidity Profile
SSP	Scientific Services Program
STAMIS	Standard Army MIS
STAR 21	National Research Council's Board on Army Science and Technology Study on Strategic Technologies for the Army of the 21st Century
STARLOS	SAR Target Recognition and Location System
STARS	Software Technology for Adaptable, Reliable Systems
STAS	Short-Term Analysis Service; Subsystems Technology for Affordability and Supportability
STB	Surveillance Testbed
STCD	Space and Terrestrial Communications Directorate
STI	Stationary Target Indicator
STIRR	Subsystems Technology for IR Reductions
STO	Science and Technology Objective
STOW-E	Synthetic Theater of War—Europe
STRATA	Simulator Training Advanced Test Bed for Aviation
STRICOM	Simulation, Training, and Instrumentation Command
STTR	Small Business Technology Transfer
STU III	A Secure Phone System
SUNY	State University of New York
SUSOPS	Sustained Operations
SV	Scout Vehicle
SWOE	Smart Weapons Operability Enhancement
T2S2	Transcription/Translation Support System
T&D	Transport and Diffusion

T&E	Test and Evaluation
TA	Test Article
TA-ATD	Target Acquisition ATD
TAAD	Theater Area Air Defense
TAC	Technical Advisory Committee (DoD/DoE); Target Analysis Center
TACAWS	The Army Combined Arms Weapon System
TACOM	Tank Automotive and Armaments Command
TACSIM	Tactical Simulation
TADSS	Training Aids, Devices, Simulators, and Simulations
TAMIP	Target Acquisition Modeling Improvement Program
TAMPS	Tactical Air Mission Planning System
TAP	Technology Area Plan
TARA	Technology Area Review and Assessment
TARDEC	Tank-Automotive Research, Development, and Engineering Center
TASM	Tactical Air-to-Surface Missile
TAV	Total Asset Visibility
TBC	Thermal Barrier Coating
TBM	Tactical Ballistic Missile
TCG	Technology Coordination Group (DoD/DoE)
TCMP	Theater Missile Defense Countermeasure Mitigation Program
TD	Technology Demonstration; Target Defeat
TDA	Table of Distribution and Allowances; Technology Development Approach; Tactical Decision Aid
TDATD	Total Distribution Advanced Technology Demonstration
TDC	Target Defeat Capabilities
TDS	Total Distribution System
TEC	Topographic Engineering Center
TECCS	Tactical Engineer Command and Control System
TEED	Tactical End-to-End Encryption
TEM	Terrain Evaluation Module
TEMO	Training Exercise and Military Operations
TEMP	Test and Evaluation Master Plan
TENCap	Tactical Exploitation of National Capabilities
TENet	Theater Extension Net
TES	Threatened and Endangered Species
TESS	Tactical Environmental Support System, Navy
TESS/NITES	Tactical Environmental Support System/Navy Integrated Tactical Environmental Subsystem
TFLOP	Trillions (Tera) of Floating Point Operations per Second
THAAD	Theater High Altitude Area Defense System
TI	Tactical Internet; Target Identification
TIES	Terrain Information Extraction System
TIIP	Topographic Information Integration Prototype
TLD	Top Level Demonstration

TM	Theater Missile
TMA	Training Mission Area
TMD	Tactical (or Theater) Missile Defense
TMD-GBR	Theater Missile Defense/Ground-Based Radar
TMG	Tactical Multinet Gateway
TOC	Tactical Operations Center
TOE	Table of Organization and Equipment
TOW	Tube-Launched, Optically Tracked, Wire Command-Linked Guided
TP	Thermo-Plastic
TRADOC	Training and Doctrine Command
TRCS	Tactical Radio Communications Systems
TRDP	Technology Research and Development Program
TRM	Threat Resolution Module
TRP	Technology Reinvestment Project
TRS	Tracking and Reporting System
TSA	Temperature Swing Absorption
TSAD	Theater Strategic Area Defense
TSAM	Theater Surface-to-Air Missile
TSD	Tactical Surveillance Demonstration
TSP	Topical Skin Protectant
TTCP	The Technical Cooperation Program
TUM	Terrain Update Module
TWG	Technology Working Group
TWS	Thermal Weapon Sight
UAV	Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
UHF	Ultra High Frequency
UHP	Ultra-High-Purity
UK	United Kingdom
ULCANS-GP	Ultra-Lightweight Camouflage Net System—General Purpose
UNITE	Uninitiates Introduction to Engineering
UOES	User Operational Evaluation System
UPAS	Unit Performance Assessment System
URI	University Research Initiative
USACE	U.S. Army Corps of Engineers
USAF	U.S. Air Force
USAISR	U.S. Army Institute of Surgical Research
USAMICOM	U.S. Army Missile Command
USAMPS	U.S. Army Military Police School
USAMRICD	U.S. Army Medical Research Institute of Chemical Defense
USAMRIID	U.S. Army Medical Research Institute of Infectious Diseases
USAMRMC	U.S. Army Medical Research and Materiel Command
USARIEM	U.S. Army Research Institute of Environmental Medicine

USASOC	U.S. Army Special Operations Command
USASSDC	U.S. Army Space and Strategic Defense Command
USCAR	U.S. Council for Automotive Research
USDA	U.S. Department of Agriculture
USFK	U.S. Forces Korea
USMC	U.S. Marine Corps
USSAARL	U.S. Army Aeromedical Research Laboratory
USSOCOM	U.S. Special Operations Command
UV	Ultra Violet
UWB	Ultra Wide Band
UXO	Unexploded Ordnance
V&V	Verification and Validation
VASTC	Virtual Advanced Software Technology Consortium
VCSA	Vice Chief of Staff, Army
VETRONICS	Vehicle Electronics
VHDL	Very High Speed Integrated Circuit (VHSIC) Hardware Descriptive Language
VHF	Very High Frequency
VHSIC	Very High Speed Integrated Circuit
VIDS	Vehicle Integrated Defense System
VIP	Video Imaging Projectile
VMMD	Vehicular Mounted Mine Detector
VMS	Vehicle Management System
VOC	Volatile Organic Compound
VOSA	VETRONICS Open System Architecture
VR	Virtual Reality
VSAT	Very Small Aperture Terminal
VSIL	VETRONICS System Integration Lab
VTOL	Vertical Take-Off and Landing
VV&A	Verification, Validation and Accreditation
WAM	Wide Area Mine/Munition
WAN	Wide Area Network
WARSIM	War Simulations
WDA	Weather Decision Aid
WES	Waterways Experiment Station
WFLA	Warfighting Lens Analysis
WG/RS	Waveform Generator/Return Simulator
Wh	Watt hour; complete unit of measurement is Wh/Kg = Watt Hour per Kilogram
WIN	Warfighter Information Network
WIS	Weapons Interface Subsystem
WMD	Weapons of Mass Destruction

WRAIR	Walter Reed Army Institute of Research
WRAP	Warfighting Rapid Acquisition Program
WSMR	White Sands Missile Range
WWCS	Waves, Water Limits, Currents, and Sediment Transport
WWW	World Wide Web
X-CRV	Experimental Crew Return Vehicle